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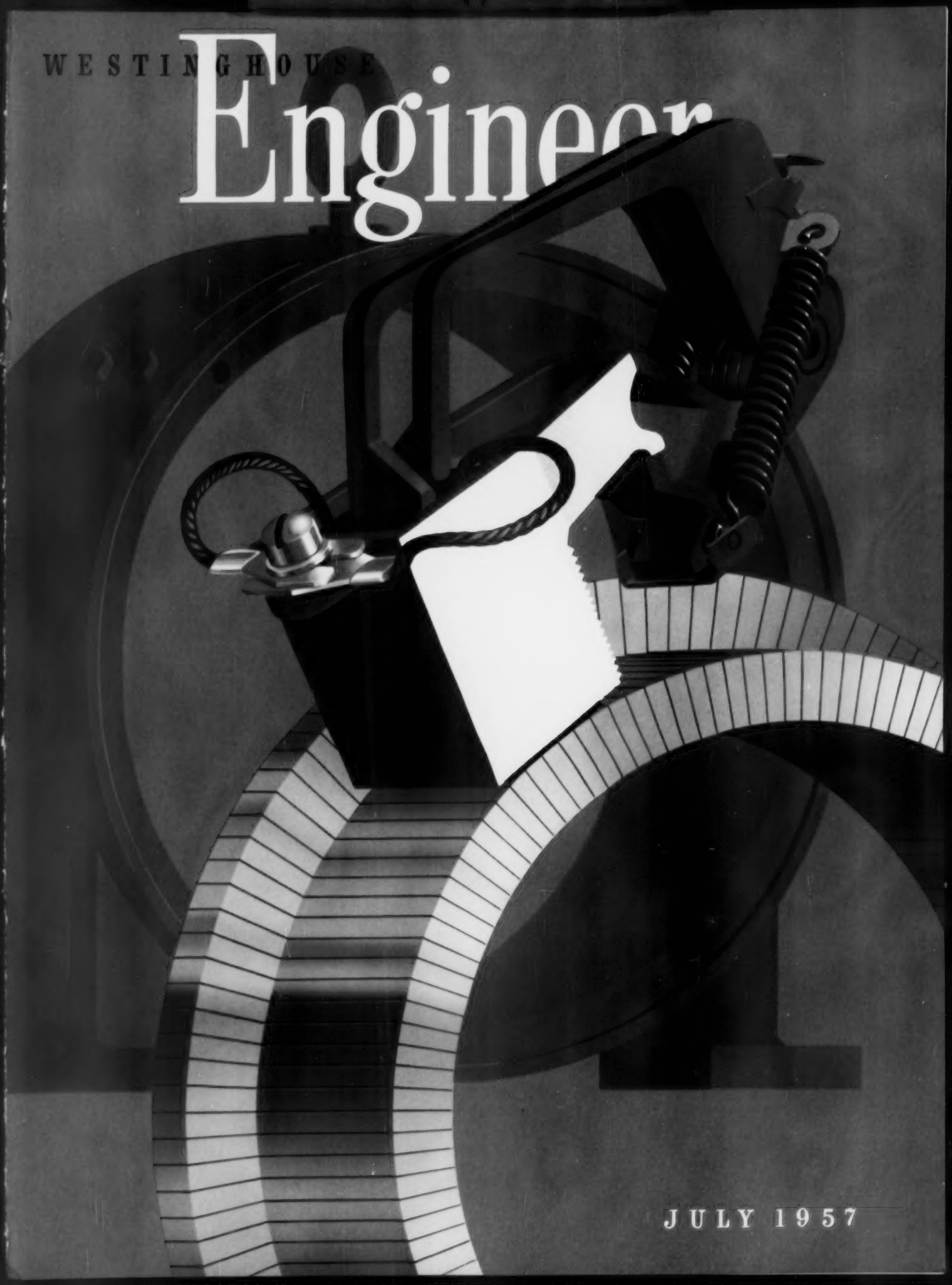
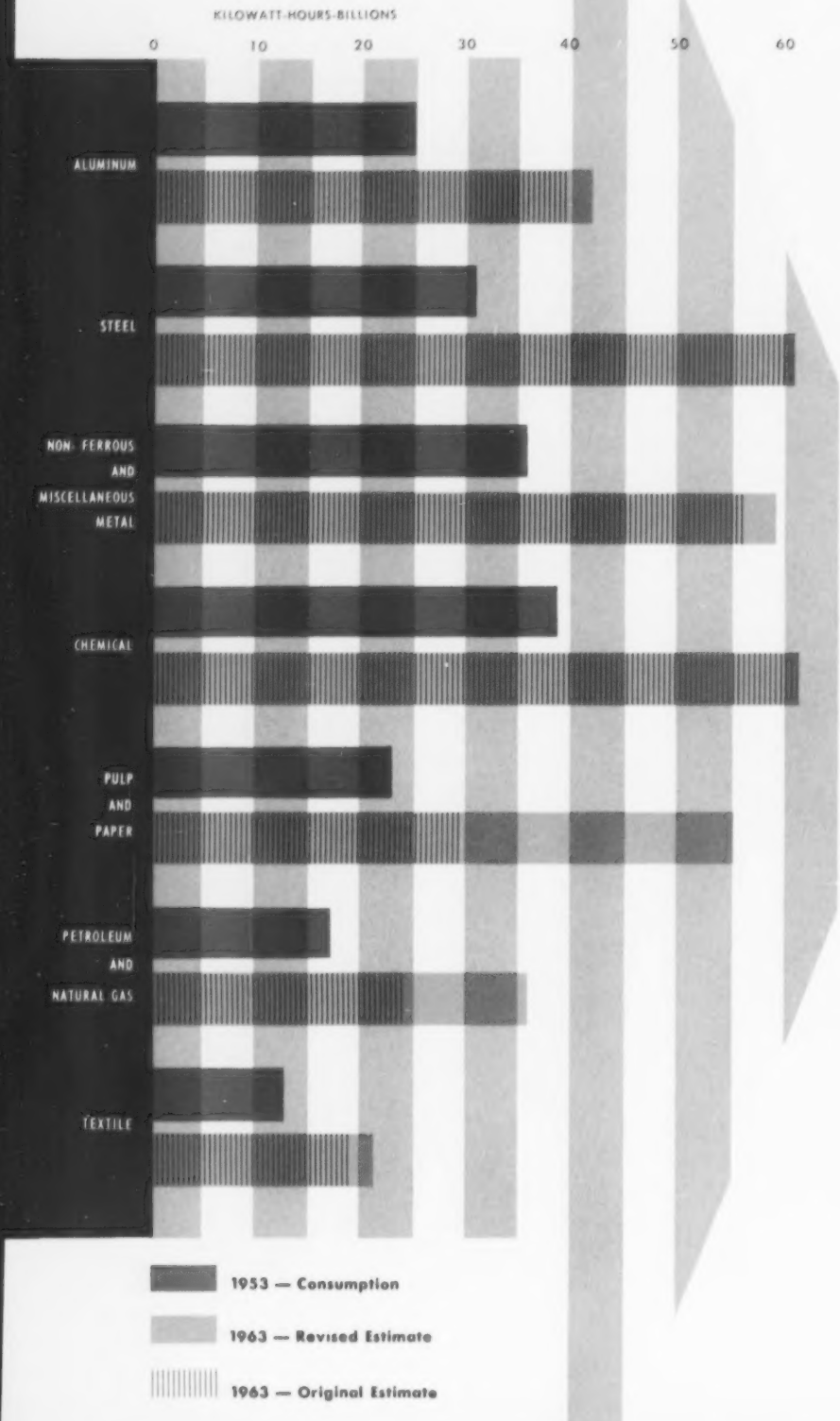


JULY 1957

Electrical Power Estimates Revised



Electric-power consumption continues to out-run predictions. At the Third Future Power Market Forum held by Westinghouse in February, 1954, ten-year forecasts were made for kilowatthour consumption in the United States. These estimates were made after long and careful studies. Yet power consumption is already ahead of schedule. As a result, the forecasts have been revised, and new estimates made for 1963.

Of particular interest are the figures for industrial power use. A comparison of the 1953 figures with the original and the revised 1963 estimates is shown at left for several basic industries. All told, the industrial power estimate for 1963 has been upped to *450 billion kwhrs*—an increase of 50 billion kwhrs over the estimate made but three years ago.

The residential use estimate likewise has been revised upward from the 235 billion kwhrs originally predicted for 1963. The revised figure for 1963 is 271 billion kwhrs—or an increase of about 15 percent over the original estimate.

An often-quoted statement is that the use of electric power is doubling every ten years. In the eleven postwar years, however, power use has been doubling every seven years. A good question is: *Will capacity soon be doubling every five years?*

Regardless of the time span, increases in power use mean expenditure of a tremendous effort on the part of the electrical industry. Sizable technological improvement must accompany this increase in power consumption. Any such increase in output, regardless of the industry, is a far more complicated task than merely scaling up existing facilities and equipment.

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VOLUME SEVENTEEN • NUMBER FOUR • JULY, 1957

In This Issue

New insulation and a new ventilation scheme are features of this new motor.

Sulfur hexafluoride gas—as an arc-suppressing medium—has made possible these two switchgear devices.

Sensing what's going on inside a turbine and recording it is the function of these new supervisory instruments.

Atomic radiations control titanium furnace—Aluminum-clad copper wire—Eliminating tv picture lines—Measuring radiation with water—New method for taking atomic pictures.

Several design improvements for overcurrent, directional, and voltage relays.

For farm and other single-phase applications, a 20-hp single-phase motor.

Given as a course for engineers, this subject aroused widespread interest.

This versatile drive, easily applied, can be used for machines that require reciprocating or oscillating motion.

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THE COVER

Brushes and a section of a commutator were chosen by artist Dick Marsh to symbolize d-c motors on this month's cover.

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View of commutator end of new motor.

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D-C MOTORS FOR MODERN APPLICATIONS

■ With the advent of all the developments popularly called "automation," d-c drives are coming again into wide use because of their inherent characteristics. The speed of d-c motors can be adjusted in an infinite number of steps, and they are adaptable to speed matching between a number of motors. Rapid but controlled acceleration, deceleration, speed changes, and reversals can be made with d-c drives. Their torque can be controlled, and they are readily applicable for electric braking. Furthermore, they are ideally suited to control by the signals that are fundamental to programmed and feedback information. A new series of d-c motors and generators, the Life-Line H design, is intended to answer these needs of modern applications.

While the inherent characteristics are responsible for the increased use of d-c motors, modern applications pose new problems in performance and dependability. Good performance with a minimum of maintenance and trouble over a long service life have always been significant requirements of electric drives. But performance and dependability are becoming even more important. Many automatic systems place new or more severe performance requirements on electric drives. Speeds must be matched more closely than ever. Faster reversals or speed changes must be made. Automatic control and regulation must be extremely close. In addition to the performance requirements, the drives must be more dependable than ever because with many operations integrated for continuous production, one motor failure can mean complete stoppage of production rather than minor schedule adjustments and maintenance expense.

A few years ago the National Electrical Manufacturers Association, recognizing the current role of d-c drives, wrote new suggested standards for d-c motors and generators in the integral horsepower range—that is, 1 to 200 hp and ¾ to 170 kw. These standards, of course, only provided a general framework for new designs.

The most significant change was the suggestion that Class B ratings be adopted—60 degrees C rise for open machines. This enables lower armature inertias for the faster response essential to modern d-c applications. A standard frame numbering system and standard frame diameters essentially identical to that adopted for a-c motors was also set up. Generator ratings were revised to more closely match individual d-c motor power requirements and standard a-c drive motor outputs, to reduce the idle capacity that existed in previous m-g sets when used to power single motors.

The standard speeds and voltages and the weak field ratings were reorganized and revised to better align with the major application of d-c—that is, adjustable voltage. Finally dripproof construction was specified as the minimum enclosure.

In contrast to a-c, the d-c standards do not specify exact frame sizes to be used nor do they assign the standard ratings to specific frames. Only the frame diameters and the frame numbering system with related dimensions are specified.

INSULATION OF THE NEW MOTORS

As mentioned, maximum dependability is a cardinal requirement. Insulation is a key factor in electrical machine dependability. Therefore, a silicone insulation system is used on the new machines. However, they are built and rated to meet the new NEMA temperature standards—only 60 degrees C rise for dripproof enclosures. The new machines thus combine high-temperature silicone insulation with the full complement of iron and copper required by low-temperature standards. The general meaning of this combination is obvious. More specifically, many tests with hundreds of "motorettes" and actual motors in the laboratories show that this new d-c insulation system will last at least 10 times as long as ordinary Class B insulation under any temperature conditions.

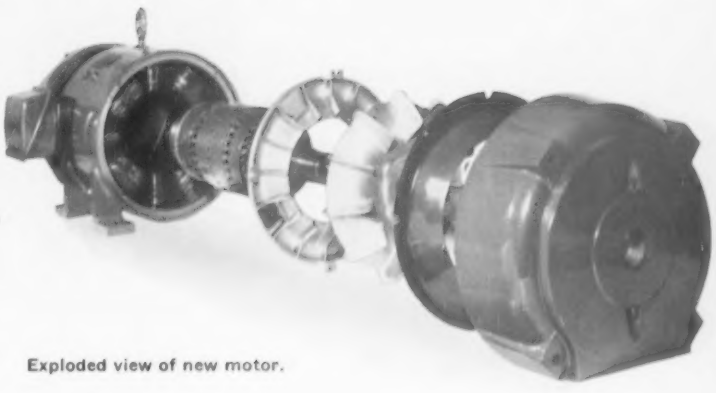
This is important to the motor user for three reasons. First, insulation is essentially eliminated as a limiting factor on motor life under normal operating conditions. Secondly, even with heavy emergency overloads or abnormal ambient temperatures, the silicone-insulated machines will go right on working in many cases where ordinary Class B insulation would fail immediately or show extremely shortened life. Finally, these machines will be able to safely handle many tough duty cycles where high current peaks would make an ordinary Class B motor unsatisfactory even though the rms average current is within the rating.

Silicone treatment is used throughout. The complete armatures are given multiple dips and completed field coils are vacuum-impregnated. Both are baked at 200 degrees C for full curing. This assures thermal stability even at extra-high temperatures. The resulting masses of copper, iron, and insulation are highly resistant to temperature, and also to liquids, vapors, and dirt. The silicone treatment is complemented by the use of molded and woven fiberglass, sheets of large natural mica flakes, asbestos, modified silicone wire enamel, silicone rubber, and other high-temperature materials for a balanced combination of thermal, mechanical, and dielectric properties.

This silicone insulation system used in machines that are built, rated, and guaranteed to meet low-temperature Class B standards is undoubtedly a tremendous step toward the ultimate dependability of d-c machines.

Standard Specifications

	motors	*generators*
Ratings	½ to 150 hp	¾ to 100 kw
Speeds	300 to 3500 base rpm	850 to 3450 rpm
Voltages	½ to 10 hp—120 and 240 volts 15 to 150 hp—240 volts	125 and 250 volts
Maximum Temperature	60 degrees C rise continuous duty	60 degrees C rise continuous duty
Windings	Shunt—compound—series	Shunt—compound
Frames	186A to 505A and 324AS to 505AS (short shaft)	186A to 505A and 324AS to 505AS (short shaft)
Enclosure	Drip-proof	Drip-proof
Starting or Inrush Current	Up to 500 percent starting	200 percent inrush
One Minute Current	200 percent throughout speed range	200 percent throughout voltage range
Speed or Voltage Range—Field Control	Up to 4:1 speed range depending on rating	Voltage range, self excited—80 to 110 percent, separately excited—residual to 110 percent
Speed Range—Armature Control	Unlimited—low speed rating depends on duty cycle	
Mounting	Foot mounted, any position	Foot mounted, any position



Exploded view of new motor.

VENTILATION

Ventilation of electric motors has a considerable bearing on their dependability. The dripproof machine, whose electrical parts are ventilated directly with room air, is the first of the new motors designed.

While ventilated machines introduce maintenance and dependability problems, often they are the best economic and engineering choice due to lower cost, smaller size, and lower inertia. Several features of the new d-c machines solve many of the traditional ventilating problems.

Not to be overlooked is the silicone insulation, which, in addition to high-temperature capacities, has exceptional resistance to deterioration by moisture and dirt. Since such deterioration is the reason for some objection to ventilated machines, the new insulation provides a significant part of the answer to traditional ventilating problems.

A fan on the motor shaft is essential to low armature inertia for fast machine response. However, the higher air flow resulting from fans can cause contamination problems inside electric machines. Therefore, the new machines include some unusual precautions. Probably the best way to explain the unusual is to first consider the ordinary. The obvious and least expensive way to incorporate a fan in a d-c machine is simply to use a centrifugal type on the shaft end. The fan throws air off its tips into the bracket and out of the machine. Air is drawn in at the commutator end and flows toward the shaft end. However, this creates some problems. External dirt and conducting particles may be thrown directly against the commutator and affect commutation. Also, the conducting dust created at the commutator by brush wear is drawn into the windings. In addition to these problems, this arrangement does not provide any control of air flow to furnish cooling where it is needed. Also, the total flow is less than it might be, particularly through the armature; with an inherently restricted opening under the commutator, the ventilating fan must pull air against the natural fans in the armature to cool this part internally.

In view of these problems, careful laboratory studies of cooling requirements and the fluid mechanics of air in electrical machines were made. As a result a new controlled ventilation system was developed. This system cleans machine parts instead of contaminating them, positively distributes air for best cooling advantage, and moves more air than other ventilation schemes.

The large aluminum fan (Fig. 1), in conjunction with an air shield and a specially designed diffuser, forces air into the machine from the drive end. This fact provides the first advantage of controlled ventilation. With air flowing toward the commutator end, conducting brush dust from the commutator goes directly out of the machine rather than into the windings. Also any external material drawn into the machine does not strike the commutator directly.

Next, note that the diffuser has separate ducts leading to the armature and fields. These positively divide the air for best cooling advantage—most to the armature where it is needed, less to the fields. Air distribution is not left to chance. Finally, with flow toward the commutator end and with positive air distribution, the natural fans in the armature add to the flow instead of bucking or preventing it. Real use is made of the armature core ducts and coil ends for cooling where it can do the most good.

The controlled ventilation scheme used in the new Life-Line H machines is also more quiet than systems in which the centrifugal fan discharges directly out of the machine. The discharge of the controlled ventilation fan into the windings provides muffling action.

PROTECTION

To supplement the dependability of insulation and ventilation systems used on the Life-Line H motors and generators, advanced external protective measures have been taken. There are no uncovered side or sloped openings in these machines. All commutator access openings have positive sealing gasketed covers. The single ventilation opening in each bracket faces down. This arrangement not only excludes dripping and running liquids, as required for dripproof enclosures, but should also eliminate the need for splashproof machines in many applications.

The brackets can be rotated to maintain the same degree of protection or obtain the desired location of vent openings regardless of mounting floor, wall or ceiling. The ventilation openings have rectangular flanges well adapted to the connection of ducts. These features not only simplify separate forced ventilation systems but suggest the possibility of using simple vent pipes to take air from nearby shop spaces that do not have undesirable material in the air.

Proper personnel protection is also provided. The air shield in the drive-end bracket not only directs air and provides additional protection for the windings, but also guards personnel from the fan. Similarly, the enclosed housing, particularly in the commutator area, is a safety feature. The Class B temperatures do not result in an extremely hot, and therefore dangerous, motor. With the ventilation system used on these machines, the temperature to the touch is little different than the previous Class A, 40 degrees C rise designs.

IMPROVED PERFORMANCE

Several major new features in the Life-Line H series improve performance considerably. First is the improved dynamic response of these machines. Fast response of electric-motor drives means not only faster processing for more output but also more accurate regulation to improve quality and eliminate process interruptions. The calculated acceleration curves in Fig. 2 show the improvement made in the new motor. They are based on 50-hp motors driving a load that demands rated motor torque to overcome resistance or friction at all times. They assume instantaneous build up of motor torque at zero time. The more than three-to-one improvement in response of the new motor is a result of two factors—lower inertia and higher commutating ability.

The new NEMA standards of Class B temperature, together with the longer frames that have been adopted, make lower armature inertia possible—about 30 percent lower with ordinary designs. However, a greater reduction—up to 55 percent lower armature inertia—has been made in the Life-Line H design because of the controlled ventilation system. With more effective armature cooling, a smaller armature is possible without any higher temperatures or sacrifice in capacity or performance.

To further improve response, commutating ability has been increased. This is reflected by the fact that the new motors and generators specify 200 percent one-minute current throughout the speed and voltage range respectively, as compared to 150 percent in previous machines. The comparative curves of Fig. 2 are based on these accelerating currents respectively. The improvement results from design and manufacturing refinements in a number of areas—brush rigging, commutator, armature, and commutating poles. The new Uniforce brushholder has several unique features. It maintains constant tension with brush wear, yet can be set for different tensions to meet special operating conditions. Double brushes with individual pressure fingers assure continuous contact. Cast and broached construction, weight balance on the support rod and radial position of brushes minimize vibration and assure best commutation, regardless of the direction of motor rotation.

Other new performance features also make considerable contributions to the suitability of this new line for high-speed automatic systems. On shunt motors and generators—those most frequently used in automatic systems—large air gaps,

oversize field coils, and special pole faces are used to give the near linear regulation that means better performance in automatic systems with less control complication. The new and old motor regulation curves of one 1750-rpm rating at full voltage and field are compared in Fig. 3. Not only is the curve of the new motor more linear but also the regulation is considerably less. Corresponding improvement is achieved with weakened field and reduced voltage.

The new shunt motors attain these stable regulation characteristics without the use of series windings in ratings up to 60 hp. This elimination of stabilizing series windings makes possible a reduction in control apparatus required for reversing the motor.

MAINTENANCE AND INSULATION

The basic features of the motor that assure high dependability have been supplemented by many items to further reduce and simplify maintenance. For example, brushholders are placed for maximum access through extra large hand holes. Pressure arms on the brushholders lock out with a flick of the finger, clear of the brush but in a positive position. With this arrangement brush changing and inspection can be done with one hand. Also, the unique spring-and-lever arrangement eliminates need for pressure adjustments during brush life. Individual brushholders are easily removed without disturbing other parts. Serrated square rods simplify height adjustments of the brushholder.

Turning to the armature, a number of features assure low maintenance. High-tensile axle steel is used in the shaft for maximum strength. The shaft can be pressed out without disturbing commutator or windings. Shrink fit of the aluminum fan assures no slipping, yet provides for quick removal and replacement by heating. A key in the shaft-fan assembly provides the positioning that avoids rebalancing when the fan is reassembled on the shaft. Bearings are packed at the factory and will operate for many years under most conditions with no added lubrication. However, greasing and drain ports are provided on all machines for use if service lubrication is desirable. All bearings have shields that exclude dirt, prevent excessive churning of grease, and meter the amount of grease that enters the bearing to protect against overlubrication. Inner caps on 365 and larger frames and rotating seals on 326

comparative acceleration curves

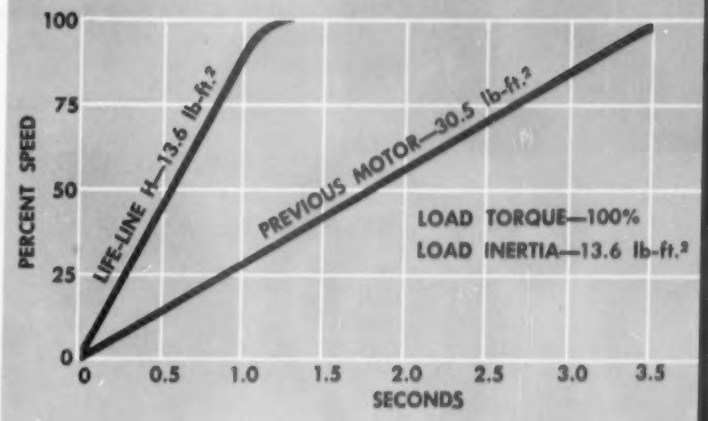


Fig. 2—Comparative acceleration curves for the new and previous machine.

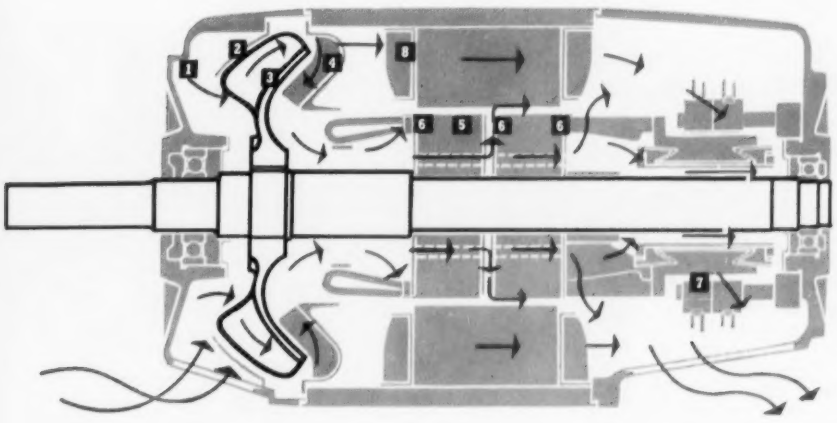
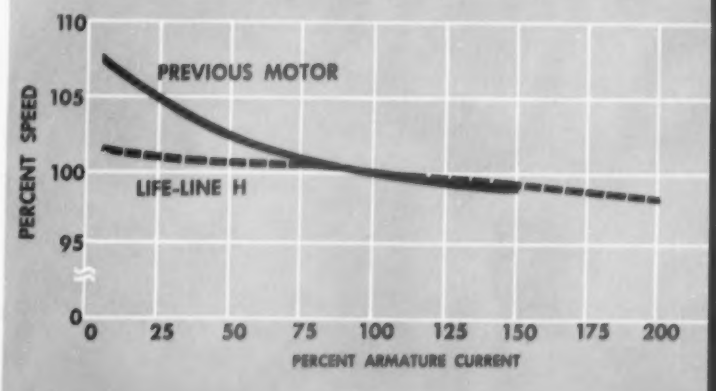


Fig. 1—This sketch demonstrates operation of Controlled Ventilation. Air is drawn in from drive-end bracket (1). Air shield (2), fan (3), and diffuser (4) work together to force air into the machine instead of out at the drive end like ordinary centifugal fans. Diffuser also divides air in proper proportion between armature (5) and fields (8). Natural fans (6) in armature aid flow. Conducting dust created at the commutator (7) by brush wear is carried directly out of the machine.

Fig. 3—Regulation curves for new and old motors.

comparative regulation curves



These photos show the access to brushes and brush mechanism.

Standard horsepower ratings are the same as before but generator ratings have been revised to better align with d-c motor demands and a-c drive motor outputs. Also, previous standard motor base speeds of 100, 150, 200, 250, 350, 450, 575, and 690 rpm have been dropped and new speeds of 650 and 2500 rpm added. A large number of generator speeds that saw little or no activity in recent years have been dropped. The previous NEMA standards listed all 50 and 60 cycle synchronous and induction motor speeds down to 75 rpm. The new standards are 850, 1150, 1450, 1750, and 3450 rpm. These are induction-motor speeds and the new d-c generators are also suitable for operation at the corresponding synchronous speeds.

Shunt, compound, and series-wound motors are provided to furnish the speed and torque characteristics required by various applications; also shunt and compound generators are provided. Typical characteristics of these types are shown in the curves in Fig. 4.

As a result of all the new features in the design of these new d-c machines, they provide the utmost in performance and dependability—prime requirements in continuous automatic production, which is becoming so important in modern manufacturing. ■

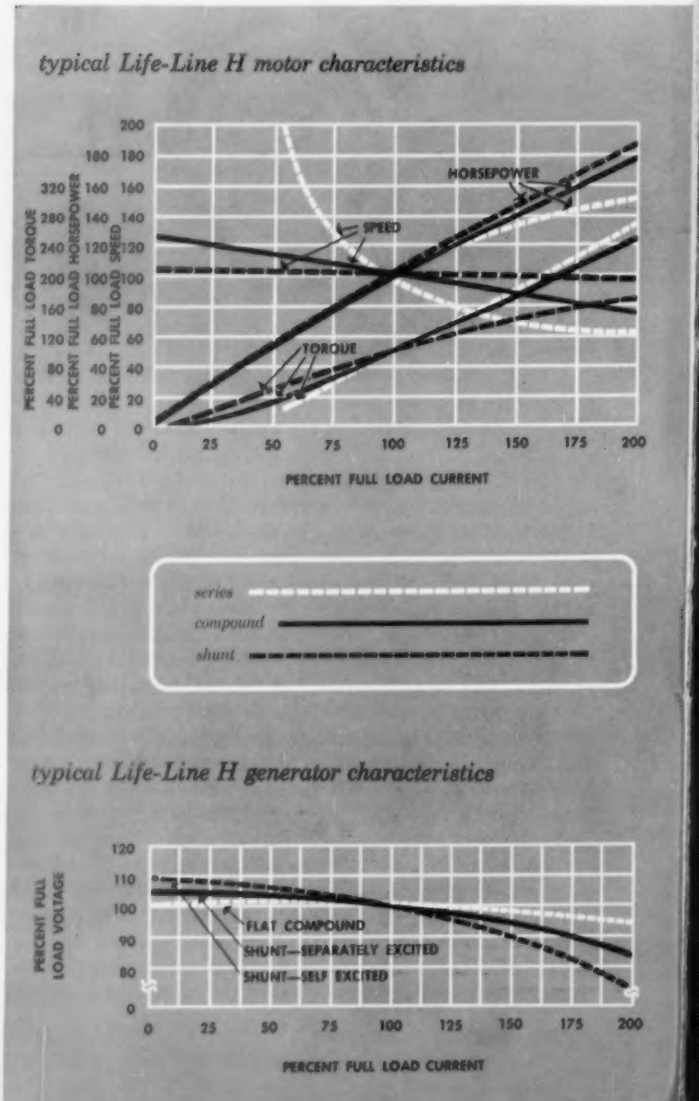


Fig. 4—Typical characteristics of shunt, compound, and series-wound Life-Line H motors.

and smaller frames are used to exclude grease from the inside of the machines.

The conduit box arrangement provides considerable flexibility and ease of installation. It is diagonally split for maximum access. A wiring diagram inside the box cover, together with lead tags marked in relief, make for simple connection. The conduit box can be rotated for bottom, horizontal or top entrance and can be mounted on either side of the machine. Up to three sizes of standard boxes are available for each frame size and the steel boxes have multiple knock-outs to accommodate three conduit diameters.

STANDARD SPECIFICATIONS

The present line covers all standard dripproof ratings up to 150 hp and 100 kw with eighteen frames from the 186A to the 505A. Frames for 580 and 680 series will be added later to complete the NEMA integral range of 200 hp and 170 kw. Totally enclosed derivatives will also be developed.

Standard motor voltages are 120 and 240 rather than the previous 115 and 230. Also, there are no "constant speed" and "adjustable speed" motors as in the past, but only a single line with speed ranges by field control varying from 1:1 for larger 3500-rpm ratings up to 4:1.

Fig. 5—Typical characteristics for shunt and compound generators.

■ The favorable characteristics of sulfur-hexafluoride gas as an arc-suppressing medium have made possible two new medium-powered switchgear devices. The mechanical operation of each is similar—a reciprocating contact operating inside a porcelain housing filled with sulfur-hexafluoride gas; but the devices serve distinctly different purposes. One *interrupts* currents of 600 amperes at voltages up to 138 kv; the other *initiates* currents up to 20 000 amperes at 196 kv. Each has a definite place on the modern utility system.

OUTDOOR LOAD-BREAK SWITCH

Electric-utility systems often need a disconnecting device to fill the void between power circuit breakers capable of interrupting large fault currents, and the disconnect or air-break switches with no interrupting rating, which are used primarily for isolation of equipment for maintenance purposes. Apparatus with just *load-interrupting* ability can be used to good advantage many places on a system where infrequent operation will not justify breakers with fault-interrupting ability. Although air-break switches have been used to open transformer magnetizing currents and line-charging currents up to 15 amperes, successful interruption is often dependent on wind conditions, and the operation can be somewhat hazardous. Typical system applications where breakers or air-break switches may not be feasible for one reason or another are interruption of transformer magnetizing currents, line-charging currents, and load currents. A new line of load-break switches have been designed to handle these and similar applications, such as isolated capacitor-bank switching, sectionalizing, load paralleling, and voltage regulator isolation.

The new load-interrupter switch (Type VLB) consists of a modern vertical-break air switch to which a porcelain-clad, gas-filled interrupter unit has been added. The use of sulfur-hexafluoride gas, with its good arc-interrupting characteristics, and a design that places the interrupter in the circuit only during the interrupting interval makes possible

APPLICATION OF LOAD-BREAK SWITCHES AND AUTOMATIC GROUNDING SWITCHES

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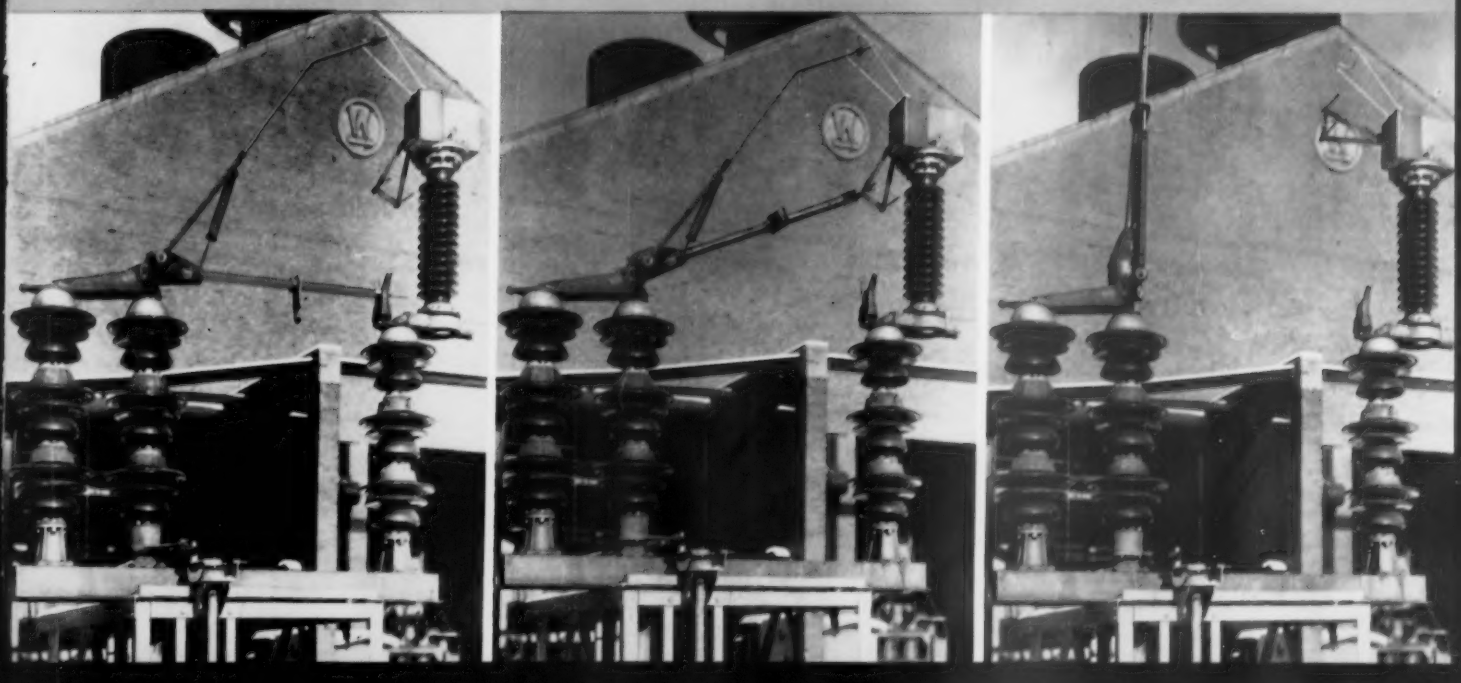
Load-interrupter switch (115 kv) in the closed position (left). The first 30 angular degrees of rotation of the center driving insulator rotates the blade and releases pressure of the stationary contact jaws. The second 30 degrees of insulator rotation (center) raises the blade from the stationary contact, diverting load current through the interrupter unit and the interrupter isolating blade. The main switch blade engages an arm on the interrupter housing, tripping the gas-filled interrupter, which interrupts load current. An arm on the main blade engages the interrupter isolating blade, and the two blades rise together during the final 40 degrees of drive-insulator rotation (right), establishing the full visible air gap required in the disconnecting switch.



a small, lightweight, and easily operable interrupting device.

The interrupter is completely self-contained and requires no external supply of gas or other auxiliary apparatus for operation. The gas is not consumed during operation, and units have long interrupting life, as demonstrated by an extensive testing program.

Interrupter elements are shown in Fig. 1. A sealed, gas-filled chamber contains an axial-flow interrupting unit. The contacts are actuated by a toggle-type spring mechanism, so that they open and close at a speed substantially independent of the operating speed of the main air switch. This spring mechanism is located in a housing on the top of the porcelain casing that contains the contacts. A shaft passing through the housing wall supports a lever that is engaged by the main switch blade to actuate the mechanism.

The interrupter contacts operate in an atmosphere of sulfur-hexafluoride gas, which has excellent arc-extinguishing properties. Experiments have shown that only six inches of contact separation are required in this medium at atmospheric pressure to interrupt 115-kv circuits. This makes possible much smaller and lighter interrupters than have previously been possible. The reduction in size and weight is particularly desirable when interrupters are to be supported on conventional disconnecting-switch structures.

Simple separable butt-type contacts operating in an SF_6 atmosphere have substantial current-interrupting ability at high voltages; this ability is further increased by a design that forces un-ionized gas through the arc formed during contact separation. This is done with a piston and a Teflon orifice carried on the moving contact. The piston compresses gas above it as the contacts separate, so that gas is forced through the orifice to aid in deionization of the arc. This simple means of bringing un-ionized sulfur-hexafluoride gas into intimate contact with the arc increases the interrupting ability of the device considerably.

A pressure gauge at the bottom of the interrupter is visible from the ground and indicates any loss of gas from the interrupter. The chamber is filled with gas at 30 psig, but will interrupt its full rating at 15 psig. The chamber is completely sealed and thoroughly leak tested. Field experience has shown that the interrupters need recharging about every $2\frac{1}{2}$ or 3 years. The loss of pressure is due to diffusion of gas molecules through the retaining materials.

Type VLB switches are made in ratings 15 through 138 kv. Each switch has an interrupting rating of 600 amperes at 50 percent lagging power factor. Tests have demonstrated a minimum operating life of 500 operations at full rating. Both laboratory and field tests have shown the effectiveness of this simple interrupting device for handling switching problems at transmission voltages.

Another important consideration is the ease of installation. The VLB load-break switch uses the same operating-mechanism components as an air-break switch. Since the interrupter is a self-contained unit mounted on the jaw insulator stack, there is no mounting complication. Installation costs are no more than for an air-break switch.

HIGH-SPEED GROUNDING SWITCHES

High-speed grounding is not new to the electric-utility industry, but in the last year a new approach has been planned and developed; as a result, high-speed grounding has an entirely new appeal.

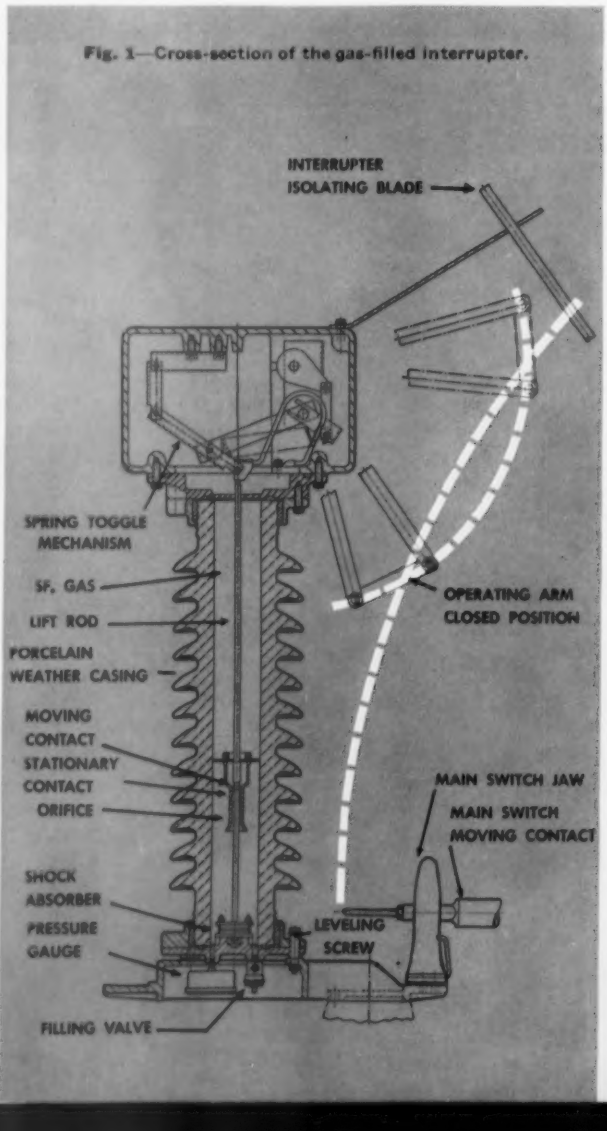
The Pennsylvania Power and Light Company asked Westinghouse to develop a high-speed grounding switch for 196-kv service, which would close 20 000 amperes in the very short period of 5 cycles, instead of the conventional time of 15 to 30 cycles. Two switches capable of meeting these requirements have been installed at the Peckville substation of the Pennsylvania Power and Light Company (below).

A high-speed grounding switch is generally used to trip a remote circuit breaker for the purpose of de-energizing an internally-faulted transformer with no local high-side breaker protection. A typical application is a step-down substation serving a remote industrial site or small community (Fig. 2), where a local high-side breaker is not economically justified simply to protect the transformer against internal faults. The high-speed grounding switch, in closing, creates a line-to-ground fault of sufficient magnitude to trip the remote circuit breaker supplying the transformer, removing the faulted transformer from service before it is damaged extensively.

Conventional high-speed grounding switches have been of the swinging-blade type, operating in an interval of 15 to 30 cycles, and rated to close 5000, 10 000, and occasionally 20 000 amperes. But with the advent of faster breaker and relay operation, the conventional grounding-switch operating time of 15 to 30 cycles has become obsolete for coordination with faster-acting breakers and relays.

Another factor involved is the susceptibility of the conventional grounding switch to icing. In the *open* position, the exposed blades can accumulate an ice load that is heavier than the blade itself; with only a fixed amount of stored

Fig. 1—Cross-section of the gas-filled interrupter.



energy available to close the blade, operating speed will decrease beyond the limits required for satisfactory service.

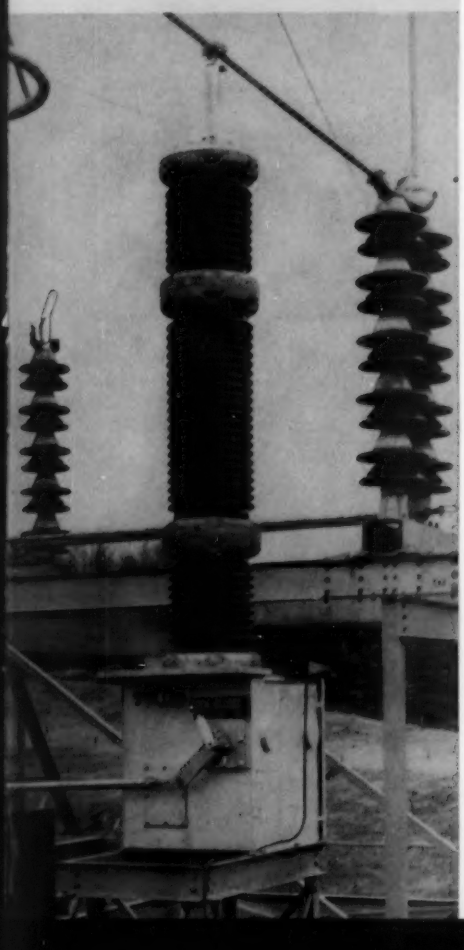
In considering the problems of the new development, design engineers decided that a completely new approach was required. Testing experience with conventional designs indicated that pivoted blades or rotating insulators would be impractical for attaining five-cycle operation. Therefore, reciprocating-blade motion in a sulfur-hexafluoride gas atmosphere was selected. A simplified cross-section of the grounding-switch pole unit is shown in Fig. 3. The open gap is located symmetrically within the porcelain. The stationary contact assembly is suspended from the top or live side of the porcelain. A similar structure houses a reciprocating aluminum blade on the ground side of the open gap. Stationary rounded and polished corona shields at the ends of the support tubes raise the breakdown voltage across the open gap and permit closer spacing of the contact assembly and reciprocating blade. The circuit to ground is completed when the reciprocating blade thrusts upward to engage the contact assembly and bridge the open gap.

The resulting high-speed grounding switch closes 20 000 amperes, is not susceptible to icing, and has an operating time of less than five cycles. It has a minimum number of moving parts and withstands repetitive operation with a minimum of maintenance. Sulfur-hexafluoride gas minimizes contact burning and allows the stationary contact and moving blade to be positioned much closer than would be possible in air, thereby minimizing closing time and making five-cycle operation possible.

The mechanism pressure chamber and porcelain are filled to 30 psig pressure with sulfur-hexafluoride gas. However, the pole unit is designed to operate at 15 psig so that a factor of safety is provided to accommodate molecular migration and diffusion of the gas through materials as is done for the VLB load-interrupting switches. Since the same gasketing techniques and shaft-seal designs are used, comparable life is to be expected.

A pressure switch is provided to make the pole unit fail-safe in the event of a fractured porcelain and sudden loss of gas. The pressure switch is calibrated to close at about 12 psig. It energizes the grounding-switch trip coil, thereby closing the grounding switch while it has sufficient gas to handle its full rating.

From the viewpoint of the utility company, the five-cycle grounding switch offers the same degree of protection in operating time as do transfer-tripping schemes; it does this with fewer parts, less maintenance, lower cost, and greater dependability. With the many components involved in carrier-current or pilot-wire relaying, these systems are likely to be inoperative much more frequently than a grounding switch, which is a self-contained device, and which functions as long as the transmission line itself is in service. ■



Five-cycle 196-kv high-speed grounding switch installed at the Pennsylvania Power and Light Company's Peckville Substation.

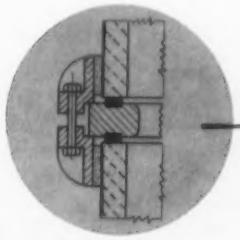


Fig. 3—Simplified cross-section of five-cycle grounding switch (right).

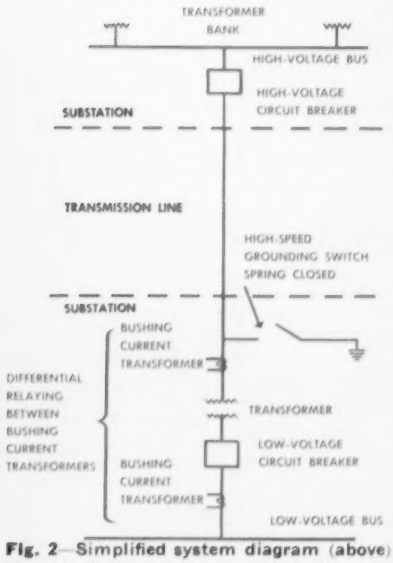
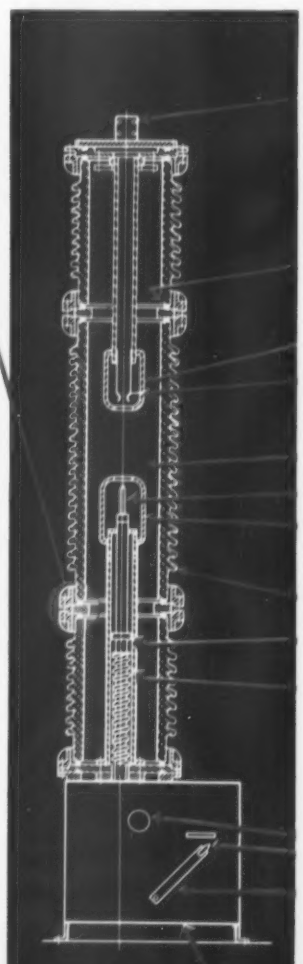
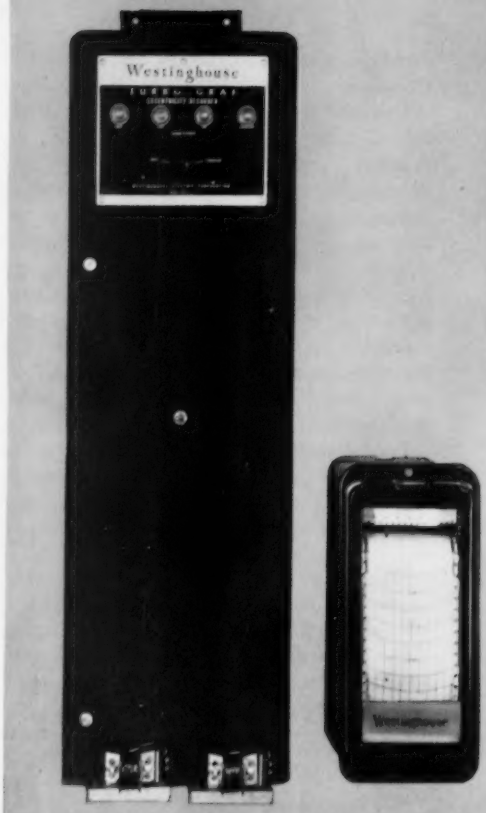


Fig. 2—Simplified system diagram (above) shows typical grounding-switch application.



a new approach to

TURBINE SUPERVISORY INSTRUMENTS



A typical new supervisory instrument. The same recorders, except for scale plates, are used on all instruments. The instrument cases . . . .

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■ Steam turbines are becoming larger in rating, more efficient, and more expensive each year. With these larger machines, the problem of giving the operator all possible information about the existing conditions in his machine becomes more and more important. Some of these conditions of a turbine are movements of only a few thousandths inch, or are buried deep down in the interior of the machine where they are not easily observed or detected by the human operator. To detect these important, but not readily observable conditions, supervisory instruments are used.

WHAT ARE SUPERVISORY INSTRUMENTS?

Steam-turbine supervisory instruments indicate electrically the mechanical motions or actions of a steam turbine in a form useful to the turbine operator in determining his future course of operation. This definition excludes temperature recorders, and power and fluid indicators and integrators.

Since a turbine is a trouble-free machine with several years between scheduled overhauls, the instrument must be able to go a long time with little trouble and without major adjustments. This long operating-life requirement means that the ordinary economic standards for the design of

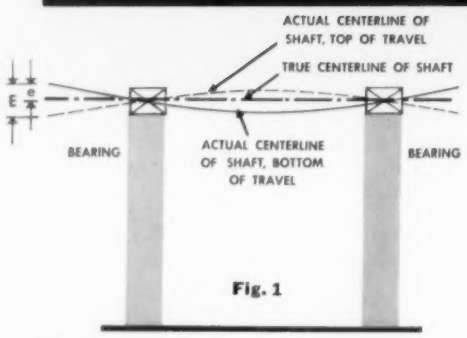


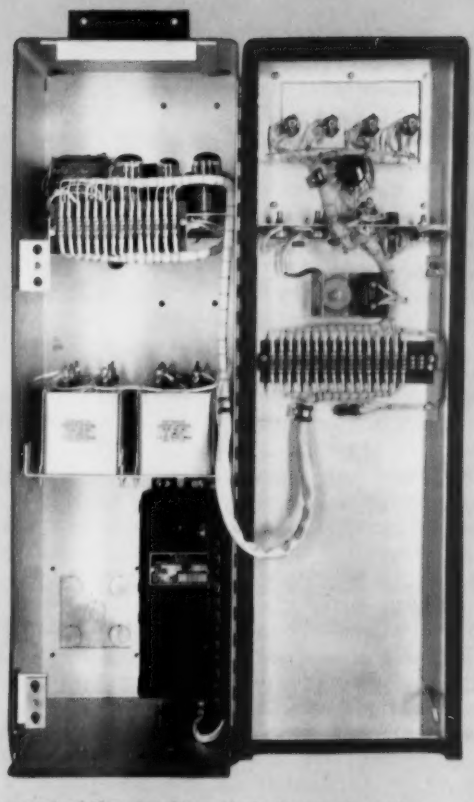
Fig. 1

e = Shaft eccentricity
E = Quantity recorded as eccentricity

Fig. 1—Bowing of the shaft between the bearings results in the center of the outboard end traveling in circles around the true center.

Fig. 2—The eccentric shaft rotates between pickup coils **PU-1** and **PU-2**. When the shaft is closer to a coil, the impedance of the coil increases and the voltage across that coil increases while the voltage decreases across its series coil which has had its air gap increased. This means that voltage **FG** changes a little as the shaft rotates; voltage **FC** changes the same number of volts as **FG** but a much larger percentage.

T2 and **T3** are like transformers, each



have part of the circuit on their doors; when the doors are open the entire circuits are exposed for easy calibration, service, or adjustment.

similar commercial and industrial electrical apparatus must be exceeded in the design of these instruments. Like any other commercial instrument, the devices must be easily adjusted and maintained.

TYPES OF SUPERVISORY INSTRUMENTS

Since the first supervisory instruments were developed, some twenty years ago, some instrument designs have been abandoned, others have been used slightly, but some five types have been widely used. These five devices are the eccentricity recorder, the vibrometer, the spindle-position recorder, the differential-expansion recorder and the cylinder-expansion recorder.

On the basis of experience with supervisory instruments, the requirements for an ideal line of supervisory instruments have been established, and a new line of instruments designed around these requirements.

The primary aim in their design is usefulness to the operator. To be of greatest usefulness to the operator such instruments should be reliable, have many like parts, have a quick calibration check available, and be easy to service. Long-term reliability is obtained in these Turbo-Graf instruments by using inductors where possible, using a minimum of electron tubes, and working all components at low values compared to their ratings.

The same recorders, except scale plates, are utilized in all instruments, thus permitting interchange of recorders. The instruments are housed in similar cases, which should be mounted under the recorders. These cases have parts of the circuits on their doors, so that when the doors are open, the entire circuits are exposed for easy calibration, service, or adjustment. One instrument is shown at left.

When the instruments are located with the case under the recorder, this calibration is easily done by one man, thus eliminating the time-honored shouting between two people, one at the recorder and one at the instrument.

THE ECCENTRICITY RECORDER

When a turbine has been still for a period—an hour, overnight, or a week—the shaft tends to bow slightly due to slight temperature differentials from one side to the other. These movements are only a few thousandths of an inch, but these tiny displacements would result in unbalanced forces of several tons if the machine were operated at rated speed. A turbine is usually operated at 1 to 20 percent rated speed until the shaft is true and these bows have been removed. The eccentricity recorder monitors the shaft during this critical period of operations.

Bowing of the shaft between the bearings results in the center of the outboard end of the shaft traveling in small

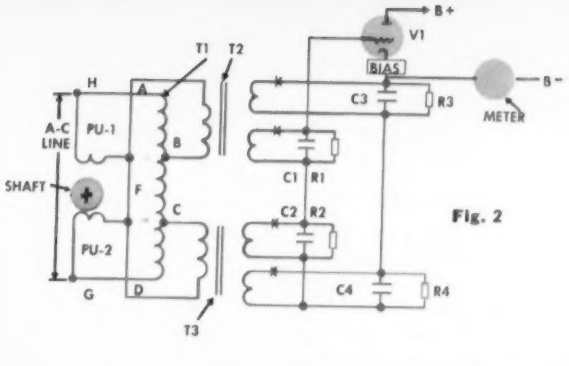


Fig. 2

with three equal windings. As the primaries of **T2** and **T3** are connected in series, the sum of their voltages is always the same as the **BC** voltage regardless of the voltage point **F**. The sum of **T2** secondary voltage and a **T3** secondary voltage is always the same as **BC** and the voltage of any secondary can vary as the shaft rotates. The outputs of all the secondaries of both **T2** and **T3** are rectified and are used to charge capacitors.

Two of these capacitors, **C1** and **C2** are shunted with large resistors so that their time constants are very long (some minutes); thus **C1** maintains a voltage that is proportional to the maximum voltage across **T2**, and **C2** maintains a voltage that is proportional to the maximum voltage across **T3**. The sum of these capacitor voltages is proportional to the **BC** voltage plus twice the change in voltage due to the shaft eccentricity.

On the other hand, the capacitors **C3** and **C4** have low-value resistors shunted across them so that their time constants are only a few cycles. Thus, the values of voltage on **C3** and **C4** are proportional to the values of the transformers supplying them at any instant and the total voltage of **C3** plus **C4** is proportional to **BC**.

By means of a tube with suitable bias, connected with its cathode on **C3** plus **C4** and its grid on **C2** plus **C1**, the **BC** voltage component can be subtracted and the tube grid allowed to be affected only by the double-eccentricity component. Thus, the tube plate current with suitable calibration can be used to display the eccentricity. As the time constant of **C1** and **C2** is very long and as **C3** plus **C4** is a constant value, the plate current changes slowly following the general trend.

circles around the true center (Fig. 1). Numerous methods have been used to indicate the variation from the center of this shaft, but most are based on the effect of the variation in the air gap between a nearby coil or coils and the rotating steel shaft, which serves as an armature for the coil. A mechanical means to indicate eccentricity is to rest the foot of a dial micrometer on the shaft and subtract the minimum reading from the maximum.

Eccentricity is not a simple number like voltage or thickness, but the difference between two numbers that exist at different times; that is, eccentricity is the difference between the maximum and minimum distance between the pickup coil and the shaft, and these conditions occur 180 mechanical degrees apart. Hence an eccentricity device must perform the following functions: (1) measure the minimum coil-shaft distance and remember this measurement, (2) measure the maximum distance of the coil from the shaft, (3) subtract the two distances, and (4) display the result of the subtraction and gradually "forget" the number remembered so it can receive changed information. The problem is further complicated by the fact that the eccentricity device is expected to measure 1 mil center displacement (2 mils of double amplitude eccentricity) of a shaft held in a bearing with, say, 15 mils clearance, and which has a tendency to move around in the bearing as speed is increased. The slow shaft speed, perhaps 1.5 rpm, and the desire to display eccentricity as a nearly smooth curve also makes the problem more difficult.

The current Westinghouse Turbo-Graf eccentricity recorder accomplishes all these things. It is shown schematically in Fig. 2. The eccentric shaft rotates between two pickup coils; when the shaft is closer to a coil, the impedance of that coil increases, as does the voltage across it. At the same time the voltage across the series coil decreases. These voltage changes, through the circuit shown, ultimately are fed to an electronic tube, one component to the grid and one to the cathode. When properly calibrated, the output of this tube, i.e., the plate current, gives an indication of eccentricity.

In turbine operation, the turbine is usually rotated on turning gear at 1.5 to 30 rpm until startup. At starting, steam is admitted and the turbine is kept at speeds less than 600 rpm until the eccentricity reads nearly zero. At the speed of about 600 rpm any residual bowing will be apparent as vibration and will be duly reported on the vibrometer as such. Thus, the eccentricity recorder should cut out, the vibrometer cut in for shaft disturbances that occur at higher speeds.

THE VIBRATION RECORDER

Vibration is, strangely enough, a difficult function for the turbine operator to detect. Usually the turbine is so well balanced that the vibration is quite small. The operator senses this small vibration, but if it increases gradually, the operator does not perceive the increase but unconsciously adjusts his perception to consider the increase as normal.

Many different vibrations occur in a turbo-generator. The shaft is the initial source and vibrates in respect to space. Some of the energy from the vibrating shaft spills over into the far heavier bearing structure, which vibrates at a greatly reduced amount, perhaps even at an altered phase angle. Some of this energy from the bearings activates the foundation, which also vibrates, again at reduced amplitude and altered phase angle. All of these vibrations are referred to as the movements of the objects in space. Because these parts vibrate at different phase angles, different vibrations still exist when any one object is taken as a reference to consider the vibration of another object.

The designer has three points at which vibration in respect to space can be measured. The first is the relatively thin whippy shaft where the vibration originates. The shaft is relatively inaccessible to instrumentation because of its rotation. The second place is at the bearing, which is accessible for measurement but varies erratically both in amplitude and phase angle from the shaft vibration. The third place is at the turbine foundation, which is also accessible for measurement; but here the vibration varies erratically in amplitude and phase from the bearing vibration, in addition to being a complex combination of all the bearing vibrations. In the new instruments the vibration of the shaft is measured, because it is the originating source.

If vibration of an object in respect to space is to be measured, a reference point must be available that stays still and does not move. Such a reference point can be obtained with a seismic mounting, that is, a large mass supported by weak springs. Because the mass is large it has considerable inertia, and requires considerable force to move it over the short time of a cycle of vibration. However, the weak springs will only transmit small forces to the large mass. These small forces are incapable of appreciably accelerating the mass until the forces change their direction and try to accelerate the mass in the opposite direction. The net effect is that the large mass with the weak springs stays still in space in spite of the fact that the supports for the weak springs may be vibrating violently.

In spite of the higher pressures and temperatures at which steam turbines are operated, new machines tend to vibrate less than units designed only a few years ago. This reduction of vibration has been carried so far by the manufacturers that shaft vibration of less than one mil (double amplitude) is common. The recorder chart reads to 15 mils on the new instrument in order to record the greatest amount of movement that may occur in emergencies.

Shaft vibration is best picked up by means of a push rod with a babbitted foot that is pushed against the oily shaft with a force of about three to eight pounds (Fig. 3). On the

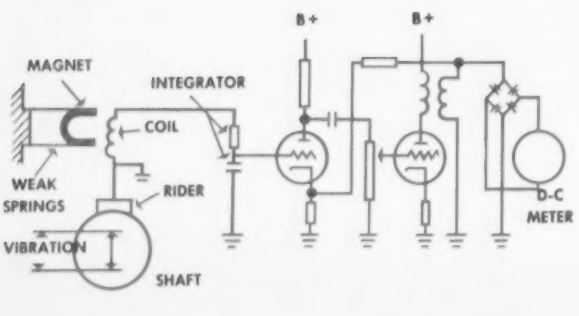
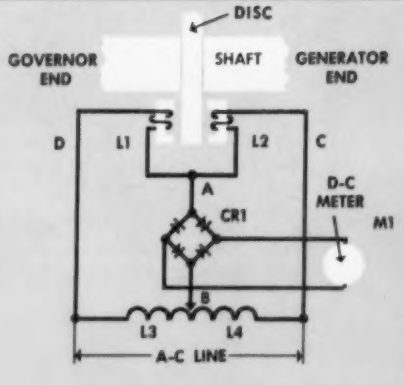


Fig. 3—In the vibration recorder, movement of the shaft is picked up by a push rod against the shaft. This movement is translated into a measurable electrical quantity



external end of this rod is mounted a coil of about a thousand turns of fine wire. This coil is in a strong still magnetic field from a heavy magnet mounted seismically. Hence, as the shaft vibrates it moves the coil in and out of the magnetic field, resulting in an alternating voltage being generated in the coil.

The greater the coil movement the higher the voltage, but a given coil movement causes the coil to cut the same amount of flux per vibrating cycle whether the coil is moved slowly or rapidly. Thus, for the same coil movement the voltage would be six times as high for 3600 rpm as for 600 rpm vibration because there would be six times as many cycles and six times as much flux cut. However, shaft movement is the desired value; flux cut per cycle is a related measurement, not coil voltage, which is a function of machine speed times flux per cycle.

To make this correction, the coil output voltage is fed into an integrator, which consists of a large capacitor and a large resistor with a time constant longer than the speed of the slowest vibration wave. The values of capacity and resistance are so large that the capacitor can be charged to only a few percent of the available coil voltage before the voltage reverses itself and the capacitor starts to charge in the reverse polarity. The peak of the a-c voltage on the capacitor is proportional to the flux cut per cycle, and therefore is proportional to vibration. This voltage is only a few millivolts because the coil moves only a short distance (a few thousandths of an inch); also the coil output voltage was greatly reduced by being applied to an integrator.

This small a-c integrator voltage is applied to the grid of a pentode and amplified. The output of the initial pentode drives a power tube, which energizes an output transformer. A secondary of this transformer supplies a rectifier, which drives a d-c recorder. Some of the voltage of this output winding is fed back in reverse phase to the cathode of the initial pentode to improve its operation of the amplifier.

Turbine vibration can change very slowly, that is, the vibration can be constant over a short period of time. The vibration varies at different positions along the shaft; hence it is customary to use a sequencing device that selects, in rotation, pickups located at different positions along the shaft, monitors each pickup for a few minutes, provides a short pause, and then monitors the next pickup. The start in a cycle is usually shown by a longer pause.

SPINDLE POSITION RECORDER

In the normal operation of a two-cylinder turbine, the thrust collar, which is a portion of the spindle, is pushing against the thrust-bearing shoes either towards the governor or the generator. Occasionally, it may hunt in the 15 to 20 thousandths inch clearance between the two sets of thrust shoes. In a single-cylinder turbine the thrust is always against the thrust shoes. Thus, the thrust collar is normally confined to a relatively small travel. Movements in excess of normal are caused by the thrust shoes being deflected due to heavy thrust loads or by wear of the shoes.

The thrust collar itself is inaccessible. However instrumentation is obtained by a disc secured to the shaft near the thrust collar and separated by a section of shaft containing little temperature gradient (Fig. 4). This auxiliary disc moves axially as the thrust collar moves.

Because of the long life required and the difficulty of correcting for wear in a contact-making device, a non-contact position-sensing device is required to determine disc positions. A reluctance bridge consisting of two similar coils mounted one on each side of the disc and a two adjustable reference arms make a sensitive non-contact means of determining disc position. A schematic diagram of such a reluctance bridge is shown in Fig. 4. Basically, the circuit makes use of the variation in inductance of the two coils (L1 and L2), and the resultant voltage drop across each, as the disc moves laterally in one direction or the other. By proper calibration the meter reads spindle position.

THE DIFFERENTIAL EXPANSION RECORDER

Thermal expansion during starting is one of the most considered factors in the design of a steam turbine. If all working parts of the machine expanded at the same rate, the problem would be complicated enough; however, in practice some parts of the machine are lighter, have a lower thermal inertia, and heat up faster than others. For example, the comparatively light spindle heats faster than the heavier cylinder and, since the two are rigidly tied together at the thrust bearing, axial clearances at some distance from the thrust are greatly changed. If these clearances change so much that they are zero or negative, the rotating parts rub on the stationary parts. To prevent this, steam is applied slowly so the cylinder can keep up with the spindle; if the spindle gets too far ahead of the cylinder, steam is reduced until the cylinder catches up.

Since expansion changes occur with temperature changes, the principle uses of a differential expansion device are when the turbine is starting or is experiencing large load changes.

The amount of expansion that can occur is in the order of 750 mils for a large machine. A 750-mil air gap in a reluctance bridge would be non-linear due to the large amount of leakage flux. The reluctance bridge has the advantage that coils are stationary and need not mechanically touch the rotating part being measured. To improve the linearity of the bridge the leakage flux must be reduced, i.e., the 750-mil gap must be reduced. The air gap may be reduced by machining a protuberance at an angle of 14½ degrees on the shaft and allowing the coil to play on this projection. Since the cosecant of 14½ degrees is four, four mils of axial movement causes an

Fig. 4—Coil L1 is mounted on the governor side of the disc and coil L2 is mounted on the generator side of the disc. The values of the inductance of the reference coils L3 and L4 are adjustable by mounting these coils facing each other, but separated by a manually movable iron slug. Thus, when the inductance of L3 increases due to nearness of the slug the inductance of L4 decreases because the slug is more remote. Thus the voltage at point B is manually adjustable. In a like manner, as the disc on the turbine shaft moves closer to, say the generator end, the inductance of coil L1 would increase and that of coil L2 would decrease. The voltage A-D across L1 would increase and the voltage A-C across L2 would decrease. With voltage B fixed, voltage A-B is a function of variation in L1 and L2 inductance, and hence of disc movement.

In operation, the value of the L3 and L4 inductors are adjusted by manual slug movement until the value of the B-C voltage is equal to the smallest possible value of the A-C voltage (disc as close to the governor end as it will ever go). As the disc moves further from the governor end, the voltage differential between points A and B increases and a larger current flows through the bridge and the recorder. Relaying, consisting of D'Arsonval relays, can be placed in series with the recorder.

air gap change of 1 mil. Thus, a maximum air gap change of 187 mils is required for 750 mils axial change and good linearity can be easily kept over this range.

The device used to measure this change in air gap is exactly similar to that used to measure spindle position except for scale markings and calibration.

THE CYLINDER EXPANSION RECORDER

The thermal changes in the metal body of the turbine when it goes from cold and still to hot and loaded make themselves apparent by expanding the entire turbine, in some cases nearly 1½ inches from cold to hot. This thermal expansion does no harm as long as the turbine expands freely on its key. If however, the turbine should stop expanding and continue to heat, large stresses might be set up that could damage the machine. Hence, a record of expansion changes is desirable as an operating aid during the starting period; this enables the operator to compare it with a normal expansion pattern.

Several methods have been used to measure this expansion. The reluctance bridge gets into non-linearity troubles due to the large gap concerned unless multiplying levers are used. Another method has a rack and gear arrangement, which rotates the transmitter of a synchrotie, whose receiver drives a recording instrument. The synchrotie transmitter was not well adapted to the high ambient temperatures of its location. The best way to record this expansion is to use the rack-and-gear drive to rotate a potentiometer (Fig. 5), which will stand high ambient temperature, and to record the voltage of the potentiometer arm, which is a function of the amount of potentiometer rotation.

SPEED-GOVERNOR VALVE POSITION RECORDER

A recording tachometer is an instrument of varying usefulness. When the machine is coming up to speed and before it is synchronized, the instrument is important and helpful. If the machine should lose electrical load and start to over speed before the overspeed trip could be effective, the tachometer record of the overspeed would be invaluable; its recording would permit the calculation of the overspeed stresses to which the machine had been subjected. Most of the time, however, the tachometer is reading synchronous speed, a fact that is apparent from the electrical frequency recording.

In both the start-up and overspeed conditions, the main governor valve is closed or rapidly closing, so a recorder that monitored governor-valve position would read zero. However, this same recorder would show a governor-valve position varying approximately as the load when the machine was synchronized. The fact that the tachometer information and the governor-valve information are not useful at the same time prompts the use of one recorder with proper relaying to record both these quantities on the same chart (Fig. 6).

This dual operation can be obtained by using switches operated by the pressure of the turbine governor oil. A turbine has a centrifugal oil pump mounted on the end of its shaft. The pressure of the oil pumped varies directly as the square of the speed. This oil pressure is used for various control functions including emergency tripping.

One switch is normally open until, say, two percent under synchronous speed, while the other is normally closed until the same percent over synchronous speed. The two switches are connected in series and conduct only at synchronous speed plus or minus two percent. The control device for the recorder permits governor-valve position indication only if the series switches are conducting. At other times, the device functions as a tachometer.

Governor-valve position is obtained by allowing an extension of a lever on the governor-valve mechanism to operate a push rod containing a rack, which finally drives a potentiometer. This potentiometer is supplied with a constant voltage and the recorder really records the voltage of the potentiometer arm, since this voltage is a function of potentiometer position and plunger movement.

The tachometer used by the new instruments consists of a permanent magnet mounted on the end of the generator shaft; supported from the generator frame (without any bearings) is an eight-pole armature that surrounds the magnet.

The a-c output of the tachometer generator is fed to a transformer with a very small iron circuit. This transformer saturates and passes to its secondary only those pulses for a few degrees before and after the zero of the a-c wave. Thus the transformer secondary receives two equal-size pulses each cycle. These pulses are rectified and displayed on the d-c recording device.

CONCLUSION

These turbine supervisory instruments record turbine eccentricities, vibrations, spindle positions, cylinder and differential expansions, governor-valve positions and speed. These instruments are rugged and reliable, use few tubes (a total of eight tubes for all six instruments). Many identical components and similar circuits are used. Test fixtures are built in for ready operation test. ■

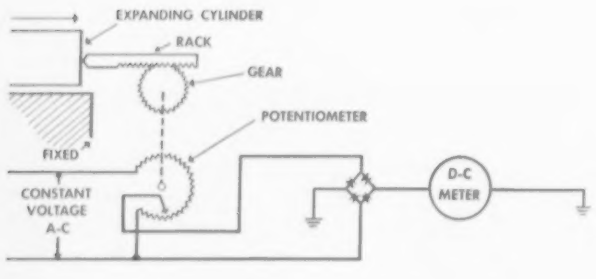


Fig. 5—The cylinder expansion recorder is used primarily during start-up of a turbine, when the entire turbine expands.

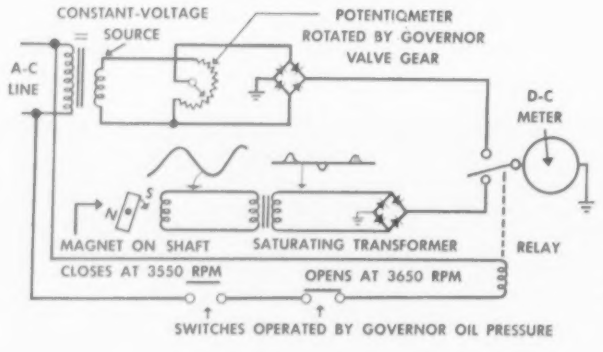


Fig. 6—The speed-governor valve recorder keeps track of both tachometer readings and governor valve information.

stories of research

Atomic Radiations Control Titanium Furnace

■ Atomic radiations, in the form of highly energetic gamma rays from radioactive cobalt, are being employed to detect and control the level of molten titanium in a new cold-hearth arc furnace designed to prepare purified titanium metal. The titanium furnace on which the control has been placed is a major installation at the Westinghouse metals development plant at Blairsville, Pa.

Successful operation of this new titanium arc furnace demands exact level control of the molten surface of the titanium ingot inside. The control must be foolproof, precise, and fast working—yet must be accomplished under extremely difficult conditions. The temperature of the liquid titanium maintained by the electric arc is more than 3000 degrees F.

Control is accomplished by beaming gamma rays through the walls of the furnace and the 12-inch titanium ingot inside. The source of gamma rays is a small needle of cobalt-60, placed in a shielded container outside the furnace and in line with the top surface of the ingot. If the ingot inside the furnace is too high, it partly blocks the beam of gamma rays, reducing the amount of radiation getting through the furnace; if the ingot is too low, the beam is interrupted less by the ingot and the amount of radiation through the furnace is greater. The gamma rays passing through the furnace are detected by means of two scintillation counters, and converted to electrical pulses. These signals are amplified and fed to electronic circuits that drive a hydraulic system, which raises or lowers the titanium ingot to the exact position required for proper operation of the arc furnace. The whole system is so precise that it can detect and maintain the titanium ingot level to within one-hundredth of an inch of its ideal operating position. If the ingot should move beyond its prescribed limits, the gamma-ray control causes immediate shutdown of the arc furnace.

Although designed by research scientists expressly for the titanium furnace, the gamma-ray control could be used on other types of furnaces and in other position-measuring and leveling applications. ■

Using this model of the heart of a 12-inch titanium arc furnace, a research scientist demonstrates an "atomic watchman" that controls the level of the white-hot titanium inside the real furnace. High-energy gamma rays, coming from the lead bomb at the left of the picture, pass completely through the furnace and are received by atomic counters inside the square metal box on the right.

Aluminum-Clad Copper Wire

■ A thin, protective aluminum skin—only two and a half mils thick—will permit copper wire to operate at higher temperatures. The copper wire is encased in a thin, protective coating of aluminum, to which is added a second coating of high-temperature insulation. The result is an enameled aluminum-clad copper wire that combines the high electrical conductivity of copper, the superior oxidation resistance of aluminum, and the added protection of a modern high-temperature insulating enamel.

In almost every new application encountered—from jet planes and guided missiles to routine jobs in industry—electrical apparatus is called upon to operate at ever-increasing temperatures. Such temperatures tend to destroy what are usually the most sought-for properties of materials, such as strength and chemical inertness. In the past, the main limitation on the operating temperatures of electrical equipment has been the available insulation. However, modern insulating materials can withstand heat so well that the copper wire around which they are placed is becoming the limiting factor.

No insulation completely seals a wire from the air, which eventually seeps through to attack the copper. At high temperatures, copper unites chemically with oxygen forming a layer of copper oxide on the wire surface. This layer gradually grows in depth, causing the insulation to degrade. In addition, it decreases the wire size, lowering its ability to carry electric current. Forcing normal current through the wire raises its temperature even higher, speeding up the oxidation process and aggravating the whole problem.

Unlike copper, the oxide formed on an aluminum surface does not grow appreciably. When only about four ten-millionths of an inch thick, it forms a self-protecting coating that prevents further oxygen penetration. Thus, a very thin coating of aluminum will effectively isolate a copper wire from attack by oxygen in the air. On an aluminum-clad copper wire about the size of the lead in an ordinary mechanical pencil, the aluminum skin is about 0.0025 inch thick. This covering must be very thin because aluminum is a poorer electrical conductor than copper and lowers the current-carrying capacity of the wire. The wire made in the laboratories has a conductivity about 85 percent of the International Annealed Copper Standard.

Biggest problem in developing a successful aluminum-clad wire was getting aluminum to adhere properly to copper, while preserving the natural ductility of the separate metals. The two metals tend to react metallurgically with each other, forming a brittle layer between them and preventing a strong ductile bond. To overcome this difficulty, a copper rod is first plated with a layer of silver, which acts as a barrier to the interaction of the two metals. In the final wire, this silver barrier layer is only about one fifth the thickness of the aluminum skin covering it. The silver-plated copper rod is then inserted into a thin-walled tube of aluminum. The aluminum-jacketed rod is rolled into a rod of smaller diameter and then is drawn through dies into wire of the desired size and shape. The finished wire is coated with a high-temperature insulating enamel, giving a double-protected copper wire with long life at elevated temperatures. ■

Research Technique Eliminates Television Picture Lines

■ The dark horizontal lines clearly visible in any close-up look at a television picture may someday be a thing of the past. Scientists have developed an experimental method for eliminating these scanning lines—now considered a natural limitation on the size of the television picture. Line elimination could be a step toward larger-size home television screens.

The standard television picture is broken up into horizontal rows, which appear as black and white lines at the television receiver. The white lines contain the picture information, which is painted by a beam of electrons that sweeps back and forth across the fluorescent screen on the inner face of the picture tube. The black lines between each pair of white ones are unexcited areas of the screen not used in constructing the picture (upper photo, right).

The new technique employs a method of wobbling the electron beam vertically as it makes its repeated traces across the television picture tube. The slight up-and-down motion of the beam broadens the white lines that carry the picture information and narrows the distracting black lines. This so-called "spot wobble" actually dates back several years, but heretofore the methods for accomplishing it have involved considerable equipment and have not been entirely satisfactory. The system newly devised eliminates these problems with a simple but basic change in the construction of the television picture tube used in all standard television receivers. This change consists of splitting in half one of the tube's cylindrical metal grids used to focus its electron beam into a tiny round spot. The split focusing grid still serves its regular function of sharply concentrating the electron beam on the screen, but at the same time, a 15-megacycle voltage can be applied. The oscillating voltage is supplied by a single electronic tube fitted to a socket into which the television picture tube is also plugged.

Spot wobble is still in its experimental stages and has not yet been adopted on a commercial scale. ■

Scientists Measure Atomic Radiations with Water

■ A new, simplified atomic detector for high-intensity radiations uses ordinary water as its sensing medium. One application foreseen for the new device is the monitoring of nuclear reactors. A nuclear reactor produces two main penetrating radiations—gamma rays and neutrons; the new detector responds to gamma rays but not to neutrons and so discriminates between the two radiations directly.

The various devices now employed for monitoring high-energy and high-intensity radiations are complicated and some are adversely affected by long exposure to radiation. A radiation monitor was desired that would be simple electrically and mechanically, and be unaffected by long atomic radiation bombardment.

The new detector fulfills these requirements by employing what is called *Cerenkov radiation* in ordinary water. Cerenkov radiation is the visible white or bluish glow that comes from water and other transparent materials when they are bombarded with high-speed particles. This glow occurs in the material only if the particles travel through it faster than light. A simple liquid such as water is ideal because it is not severely broken down chemically or physically by high-energy radiation, and can be replaced easily if any deterioration does occur.

The new radiation detector uses a light-sensitive electronic device, similar in function to an ordinary electric eye, to detect the visible Cerenkov radiation produced by high-energy atomic particles. The eye is placed some distance from a vessel containing the water, where it intercepts the visible light and converts it to an electric current.

The faster the atomic particles entering the water, the brighter the visible glow and the greater the electric current generated by the electronic eye. The current becomes a measure of radiation intensity.

The simplicity and high output of the detector make it an ideal instrument for monitoring high-intensity atomic radiations such as those used for preserving food, vulcanizing rubber, and other applications. Although the full potentialities of

These photographs of the same television picture tube illustrate the effect of the improved method of "line structure reduction." To eliminate the dark horizontal lines normally present in scanning the picture (top), the electron beam is "wobbled" as it sweeps back and forth across the face of the tube (bottom).

the device have not yet been explored, research scientists expect further development to produce uses generally in the radiation industry and for monitoring nuclear reactors. ■

New Method for Taking Atomic "Pictures"

■ Scientists have perfected a new technique for taking pictures of the atomic "insides" of metals and other crystalline materials. The technique employs a new means for detecting the neutrons that are shot through the crystal. This new process is several hundred times faster and more sensitive than methods previously used, and promises to yield important new information to scientists about the atomic architecture of crystalline materials.

For years scientists have been using beams of high-power x-rays to probe crystal structure. In passing through the crystal, x-rays are scattered, or diffracted, by the atoms in the crystal. The x-rays are then allowed to fall on a photographic film where they produce a picture of the crystal's atomic arrangement. This is a fast, accurate and extremely valuable research technique. More recently, with the advent of nuclear reactors, it was found that a beam of neutrons is diffracted in a similar fashion. Furthermore, neutrons will reveal the crystal structure of many thousands of different materials that are either impossible or impractical to analyze by x-rays.

Until now, getting a satisfactory picture of the diffracted neutrons has been difficult. This is because standard photographic film is "blind" to neutrons. Exposures of many hours were required with standard neutron sources. Secret of the new technique is an improved method for making the neutrons visible to a photographic film.

After being scattered by a crystal, the neutrons are allowed to strike a special fluorescent screen placed next to the film. The screen is made by embedding a phosphor in a thin layer of special glass or plastic, which contains atoms of boron. The neutrons pass through the photographic film and strike the screen, where they smash into the boron atoms, releasing tiny, powerful atomic particles that cause flashes of light on the screen. These flashes are recorded by the photographic film, giving an exact picture of the diffracted neutrons.

The new technique will expedite the analysis of crystals of magnetic materials, which cannot be done with x-rays. Unlike x-rays, neutrons are tiny magnets. They interact with the bombarded atoms of a magnetic material and disclose its magnetic structure. This information is helpful in understanding the magnetic properties of materials and in designing new and better ones.

Neutron diffraction is also an increasingly important research technique in studying the structure of organic materials. Organic compounds constitute some 90 percent of the known substances of earth, and all of them contain hydrogen atoms; however, hydrogen atoms do not scatter x-rays well enough to permit their identification in a crystal structure. Hydrogen atoms do scatter a beam of neutrons, so that scientists expect to learn much more about the exact structure of organic crystals. ■

Stresses in Nuclear Reactor Shell Made Visible

■ Scientists have found a way to see and study the complicated stresses existing deep inside the solid steel pressure vessel of a power-producing nuclear reactor. The technique uses a model made of special plastic to make visible the stresses in the full-scale pressure vessel—the large, complex steel structure that houses the reactor core. Use of the technique will help speed pressure-vessel design and insure that this vital structure can easily withstand any design pressures it may be called upon to contain.

A 50-pound block of ice is used to demonstrate Cerenkov radiation, the scientific principle underlying a new high-speed atomic-particle detector.

This glowing model enables research scientists to study the stresses deep inside the pressure vessel of a nuclear reactor.

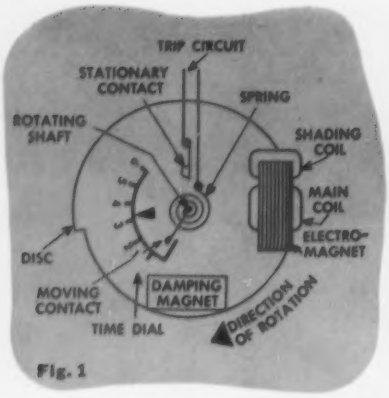
An exact model of the structure to be studied is constructed from a photoelastic resin, or plastic. Such resins have the ability to show visibly the twisting, bending, or other stresses they undergo when various forces are applied to them. When examined under polarized light, the stresses show up as patterns of colored light.

The plastic pressure vessel model is about two feet high, $1\frac{1}{2}$ feet in diameter, and weighs about 100 pounds. After the model is cast, it is machined to exact shape. Air is then pumped into the model until it is under a pressure of about four pounds per square inch—a pressure large enough to produce in the model the exact stress patterns that will exist in the actual pressure vessel under its working pressure of about one ton per square inch.

The model is then cured by heating, which freezes the stress patterns permanently into the walls of the model. Samples are cut from the model and examined under polarized light. The frozen stress patterns can be studied rapidly and with great precision.

This is the first time that photoelastic stress analysis has been applied on the scale required for study of a reactor pressure vessel. It has been made possible by the recent discovery of a new improved photoelastic resin. Compared to previous materials, this new resin is three times more sensitive in forming the desired stress patterns. The new resin also makes possible much larger models than before. A structure as complicated as a pressure vessel can be duplicated for photoelastic analysis only by taking full advantage of this increase in model size.

The success with current studies indicates that the technique will soon be applied to many structures equally complicated and difficult to analyze by other means. ■



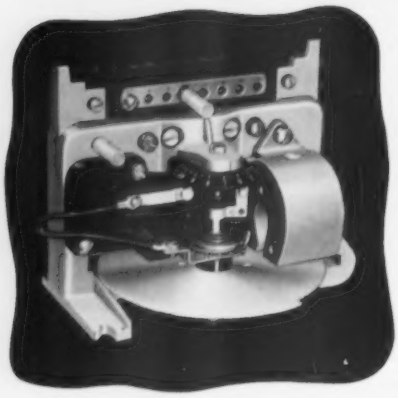


Fig. 1—The fundamental components of the induction-type time-delay relay: The operating torque on the disc produced by the electromagnet moves disc against tension of coiled spring. The damping magnet provides restraint when disc is moving. The total disc movement is set by adjusting the starting position of the disc (and moving contact) with the time-dial stop.

Photo—New CO overcurrent unit.

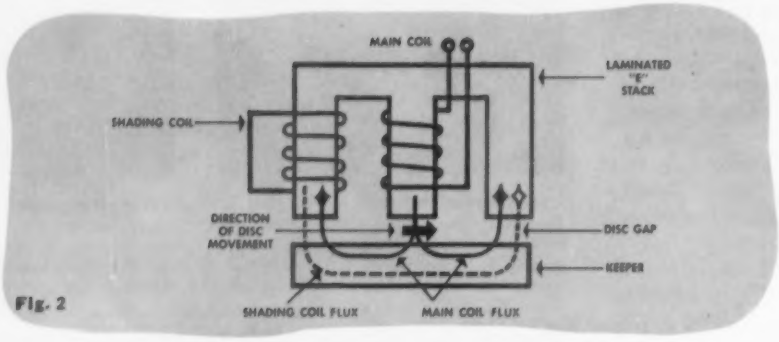


Fig. 2—This shows the design and flux path of the new "E" type electromagnet: The main coil on the center leg produces flux which divides and returns through outer legs; the shading coil causes flux in its leg to lag main-coil flux; the out-of-phase fluxes thus produced in the electromagnet air gap create the disc torque.

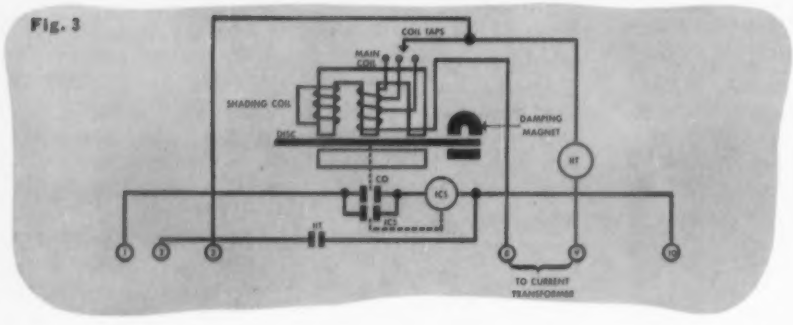


Fig. 3—Schematic diagram of type CO overcurrent relay: When overcurrent (from current transformer) occurs, disc moves, closing CO contact; this energizes ICS (indicating contactor switch) coil, and ICS contacts also close, shunting CO contacts; on extremely high overcurrents, IIT (indicating instantaneous trip) coil picks up, closing IIT contacts.

MODERN CONCEPTS of RELAY DESIGN

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■ The increasing demand for more electric power necessitates additional generating capacity, higher transmission voltages, and increasing interconnection between utility systems to assure the continuous service required. All of these changes produce more complex power networks—none of which could operate reliably without the supervision of protective relays. Protective relays function to prevent damage to power-system apparatus during fault or overload conditions, and reduce the effect of these abnormal conditions on utility-system operation. Reliability, then, is the essence of design, manufacture, and performance of the protective relay. Consequently, design effort on a new line of protective relays was directed toward improved performance, simplified construction, and minimum maintenance. Naturally, reliable performance was the fundamental absolute requirement.

The complete line of the CO overcurrent, CR directional overcurrent, and CV voltage relays has been redesigned and enclosed in a new improved Flexitest case of modern appearance. Since power-system expansion requires added panelboard space for protective devices, mounting space is also an

economic factor worthy of consideration. One-third smaller than previous designs, eight relays can now be put in the space formerly required for five.

Basically, only two significant operating units are involved in the three relay types. These are the "E" electromagnet used for overcurrent or overvoltage detection, and the cylinder-type directional unit for detecting direction of power flow. The two auxiliary units that have been redesigned are an indicating contactor switch, which indicates relay operation and shunts relay contacts, and an indicating instantaneous trip, which provides high-speed protection from heavy fault currents and indicates operation.

OVERCURRENT RELAYS

The CO overcurrent relay operates on the induction-disc principle. An electromagnet produces a torque, causing rotation of the induction disc (Fig. 1). The moving contact of the relay is clamped to an insulated portion of the disc shaft. During an overload, the disc rotates until contact is made with the stationary contact and the trip circuit thereby energized. A damping magnet restrains motion of the disc and is partially responsible for the characteristic of the operating-time curve.

A newly designed electromagnet, designated the "E" electromagnet, combined with a high-strength alnico permanent magnet for damping, provides seven different operating-time curves without the use of gearing, including designs that previously required gearing. The operating principle of the new electromagnet is shown in Fig. 2. Use of this new electromagnet design has achieved a general reduction in the burden —in some instances from 17 volt-amperes to approximately 4 volt-amperes. The new electromagnet is used in the com-

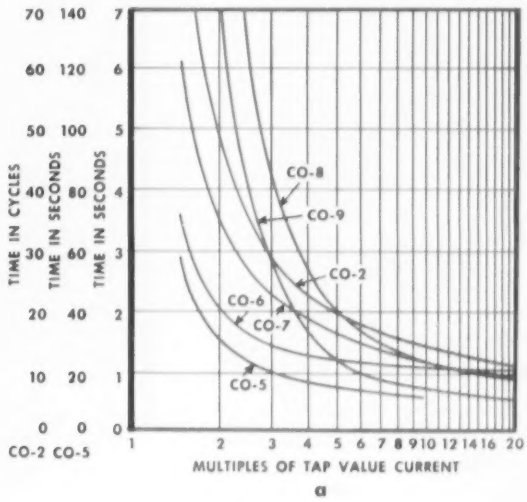
TABLE I

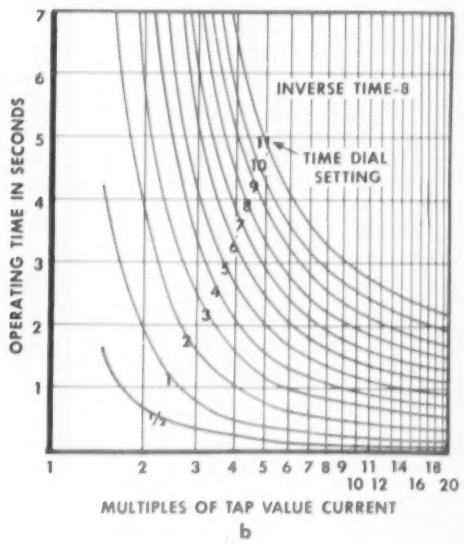
Summary of the CO overcurrent relay types and their application.

relay type	time curve	reference operating time*	common applications
CO-2	short time	.47 sec	Differential protection of bus or generators where restraint windings are not required. Straight overcurrent protection where short operating time is necessary for system stability.
CO-5	long time	25 sec	Motor protection. Long-time setting (150 percent of full load) prevents tripping due to motor-starting currents and allows motor to carry moderate overloads for safe periods. Inverse characteristic provides faster tripping at higher overloads. For protection against heavy faults during starting, use relay with instantaneous overcurrent unit.
CO-6	definite time	2 sec	For use where generating capacity and fault currents vary over a wide range. Relay has fixed operating time (per time-dial setting) from approximately 10 to 20 times tap current, thus providing definite selective operation for sequential tripping.
CO-7	moderately inverse	2.48 sec	Overcurrent phase and/or ground fault protection of transmission or feeder lines. Relay approaches definite time characteristics at high currents, allowing wide changes in fault current magnitude with little change in operating time. Useful applications: where moderate changes in generating capacity occur, or on parallel lines where one line may be called upon to carry both loads.
CO-8	inverse	2.52 sec	Phase and/or ground protection of subtransmission lines or feeders. Applied as primary protection or back-up for other relays. Wide variation in time-lever settings and slope of curves facilitates coordination, assures selective operation. Degree of inverseness required is determined by fault-current magnitude, operating time desired, and the characteristics of nearby relays on the system.
CO-9	very inverse	1.53 sec	
CO-11	extremely inverse	0.8 sec	Used on feeder circuit breakers that must coordinate with main- and branch-line sectionalizing fuses. Also used where long time delay is required for light overload, such as where feeder is energized after extended outage.

*Relay operating time on no. 10 time-dial setting with 10 times tap current applied.

Fig. 4—(a) Comparative curves for CO overcurrent relay. All curves are for the number 5 time-dial setting. (b) The effect of varying the time-dial setting is shown for the CO-8 relay.





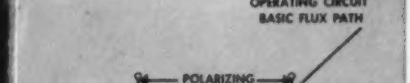
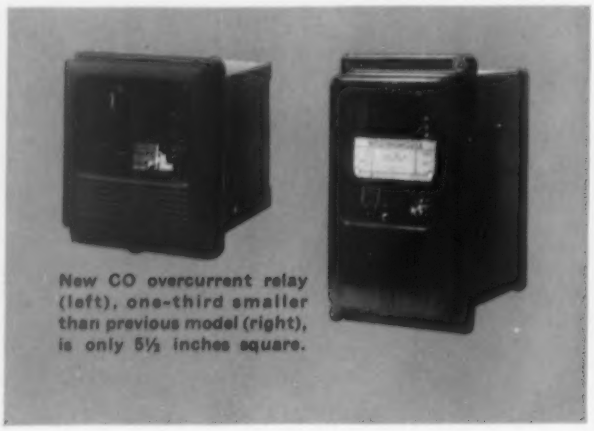


Fig. 5

plete line of CO overcurrent relays (Table I). The electromagnets of the CO-2 and CO-11 relays employ an additional winding on the right leg of the electromagnet to obtain the desired operating characteristics.

Control of disc movement (operating time) in the relay was originally achieved by moving a horseshoe damping magnet laterally with respect to the disc center. Thus the torque arm of the magnet was varied, with a corresponding effect on the speed of rotation. The new alnico damping magnet is permanently located with respect to the disc center point, with the "drag" of the magnet on the disc controlled by varying the keeper (flux shunt located below the disc), which controls the amount of flux cutting the disc. The more flux cutting the disc (the less spacing between magnet and keeper) the slower the disc speed for a given operating current applied to the main coil.

The disc is spiral-shaped to compensate for the spiral spring "windup," and introduces a greater amount of disc surface



New CO overcurrent relay (left), one-third smaller than previous model (right), is only 5½ inches square.

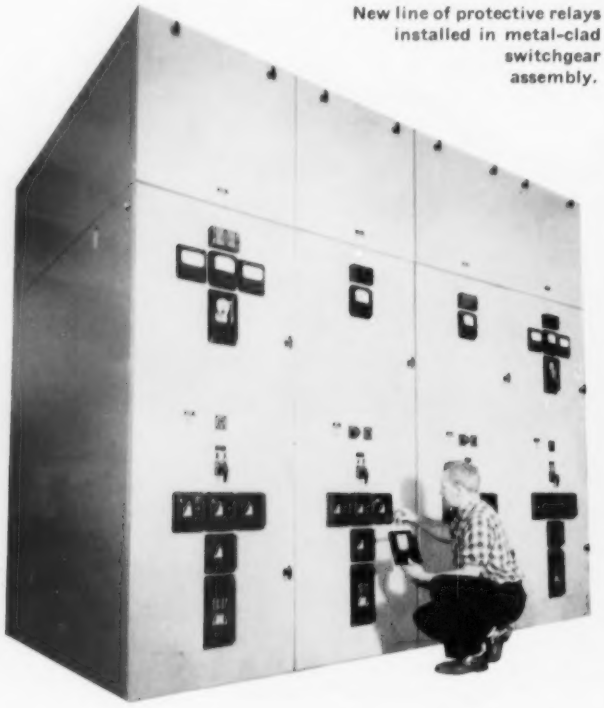
or driving medium into the electromagnet gap as the disc rotates toward the contact-closed position. Thus accurate operating time is secured over the entire range of the operating-time curve.

Operating-time characteristics of these relays are calibrated by adjustment of (1) spiral control-spring tension, (2) damping-magnet drag, and (3) magnetic plugs in the electromagnet flux path. Taps are provided on the main-coil winding to select the desired current-transformer pickup current. The time dial provides a means of setting the total travel for the rotating disc. Once the desired current-tap setting and time-dial position have been selected, the minimum pickup point is obtained by balancing the effect of control-spring restraint against electromagnet operating torque. The characteristic of the operating curve at low-current values is controlled by adjustment of the permanent-magnet keeper, while at high currents, the operating characteristic is adjusted by controlling saturation of the electromagnetic circuit with the magnetic plugs.

Because of the variance in curve nomenclature among manufacturers and also because of changes in designs of overcurrent relays, a numerical designation of curve identification has been adapted. The new designations are shown in Table I. Generally, the higher the numerical designation, the more inverse the curve and the faster the relay operates for a given amount of applied operating current.

A schematic diagram for the new CO overcurrent relay is shown in Fig. 3. Included in this diagram are the ICS (indicating contactor switch) and the IIT (indicating instantaneous trip) units. Each is a clapper-type mechanism, whose armature carries a moving contact that bridges two stationary contacts when the operating coil is energized above pickup value. The ICS contacts parallel the main relay contacts and assure trip-coil energization for sufficient time to trip the associated circuit breaker. They also relieve main-relay contacts of heavy trip currents. An orange-colored target indicates trip-circuit completion. The new ICS unit combines the seal-in switch and the operation indicator into a single unit.

New line of protective relays installed in metal-clad switchgear assembly.



The ICS unit is tapped to provide armature pickup at either 0.2 or 2 amperes d-c.

The IIT unit, an a-c operated switch, is similar in construction to the ICS unit, except its current-pickup value is adjustable over a one-to-four range by varying a core screw within the core coil. The IIT contacts are wired in parallel with the main-relay contacts (Fig. 3) and will trip the circuit breaker independently of the relay contacts if a fault current at or above pickup setting of the IIT unit occurs. Depending upon the time-current characteristics selected, the operating time of the CO relay can be several seconds, whereas the IIT unit operates in 10 milliseconds at 300 percent of minimum pickup current. The dropout-to-pickup ratio of the IIT unit is 65 percent at minimum setting and graduates to 90 percent at maximum setting.

DIRECTIONAL OVERCURRENT RELAYS

Modern relay systems often call for protective relays that trip only when power flows in a given direction. By combining a directional unit with an overcurrent unit, the relay becomes sensitive to current direction and magnitude. The new line of directional overcurrent relays has been created by combining a newly designed directional unit with the new CO overcurrent unit. The directional unit has many advantages over its predecessor in speed, freedom from vibration at high cur-

Sensitivity Curve

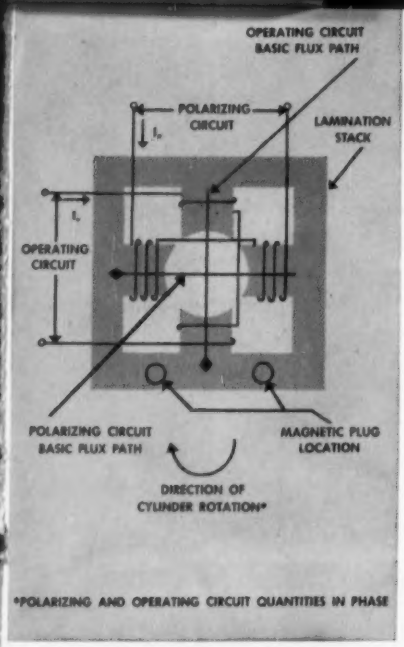


Fig. 5

rents, plus a controlled phase-angle and sensitivity curve. Also, size of the unit has been reduced and construction simplified.

The directional unit is a product-type device, held in the open-contact position by a spiral spring when de-energized. When the polarizing and operating circuits (Fig. 5) are energized in the proper direction, the cylinder rotates to close the operating contacts. The previous design employed an induction disc, whereas the new unit uses an aluminum cylinder, which rotates in an air gap between the magnetic core and the electromagnet shell.

Screw-type magnetic plugs are used in the laminated electromagnetic circuit of the directional unit to vary the basic flux pattern. The plugs control the locus of the sensitivity curve at low voltage and high current to assure a definite pickup of the unit even at very high currents and low voltage—as exist during close-in faults. Without plugs, the sensitivity curve bends away from the current axis due to spurious torques and would therefore affect the sensitivity at high currents (Fig. 7). Likewise the locus of the zero-torque line of the phase-angle curve is made a straight line, assuring contact-closing torque for a complete 180 degrees even at high currents. The plugs can also be utilized to positively close the directional-unit contacts on current alone if the relay application so requires.

Vibration is an important design consideration since it affects the required operating time of the overcurrent unit, which is directionally controlled by the contacts of the directional unit. Effective vibration is magnified as the zero-torque line is ap-

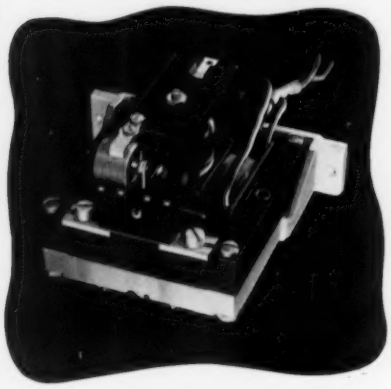


Fig. 5—Schematic diagram of the directional-unit electromagnet: When fluxes produced by polarizing and operating windings are out of phase, a "rotating field" is created, which rotates cylinder in the direction of field rotation.

Photo—New CR directional unit

Fig. 6—Schematic diagram of the CR directional relay: When current exists in tripping direction, directional unit operates to close CR contact, which closes shading-coil circuit permitting CO relay to operate; if overcurrent is sufficient, CO overcurrent relay picks up.

proached. Vibration of the moving element of the directional unit at high currents was eliminated by using an aluminum-cylinder element instead of a cup-type element.

Minimum pickup of the CR directional unit is 2 amperes and 1 volt for the 2-6 ampere relay, and 4 amperes and 1 volt for the 4-12 ampere relay when fault current leads the polarizing voltage by approximately 30 degrees. The new directional unit operates in 8 milliseconds when 20 amperes, 120 volts, 60 cycles is applied. A reduction of over 50 percent of the burden of the potential circuit plus a reduction of current burden has been attained in the directional unit. This permits greater loading of existing current and potential transformers.

The various types of directional overcurrent relays are summarized in Table II. A typical application of the type CR directional unit is shown in Fig. 8. Here three relays are used, one for each phase, to give directional overcurrent phase protection.

A comprehensive study of directional-unit connections under widely varying power-

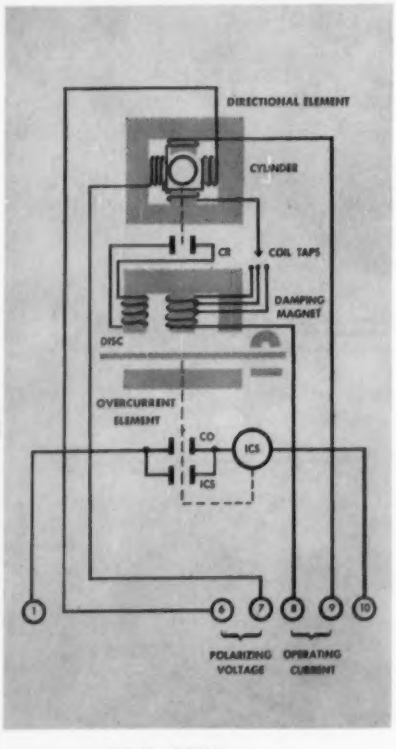
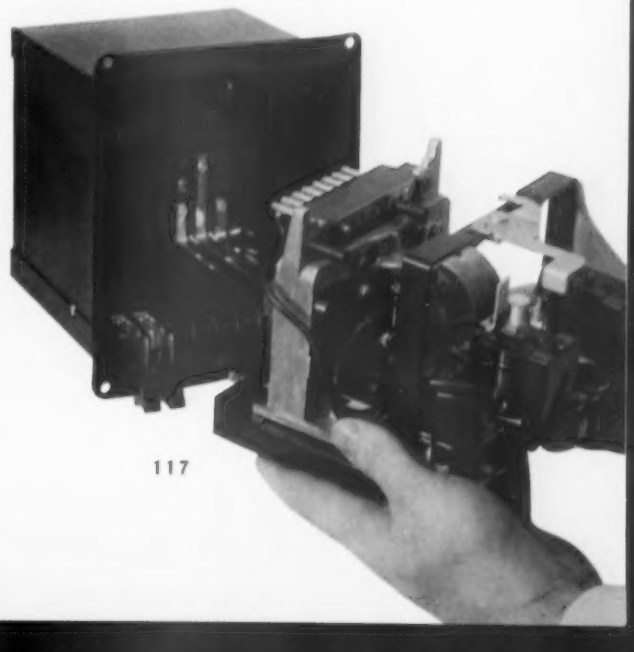


Fig. 6

Compactness in design of the new line of relays is shown by the CO overcurrent relay.

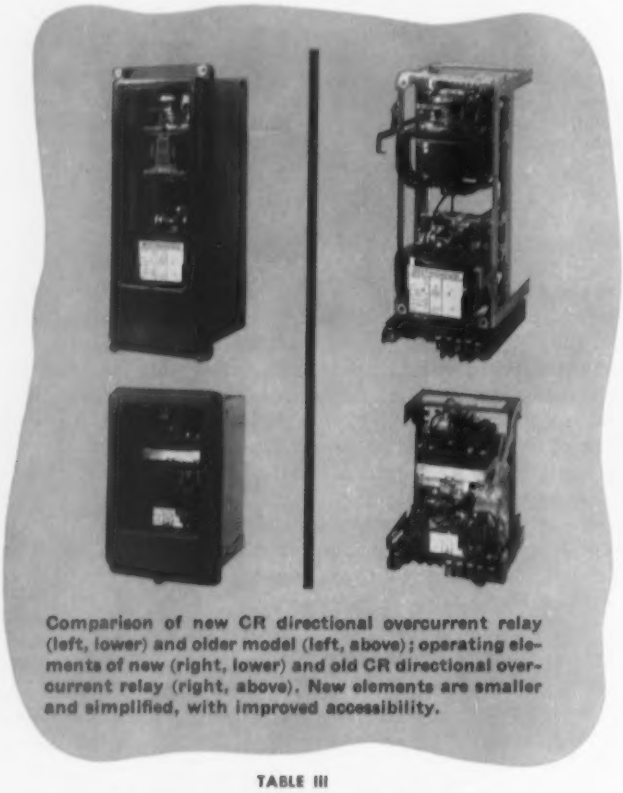


system conditions indicated that although all types of phase-directional unit connections had possible areas of undesirable operation, the 90-degree connection (relay current leading relay voltage by 90 degrees with unity power factor flow in the tripping direction) afforded the greatest degree of reliability. A subsequent study indicated that the optimum maximum torque angle of the directional unit occurs when the relay current leads the relay voltage by approximately 30 degrees. This maximum torque angle is inherent in the design of the new unit so that no internal phase shifters are

TABLE II

Summary of the directional-overcurrent relay types.

Protection	Directional Unit	Time Characteristics				
		Definite	Moderately Inverse	Inverse	Very Inverse	Extremely Inverse
Phase	Voltage Polarized	CR-6	CR-7	CR-8	CR-9	CR-11
Ground	Current Polarized	CRC-6	CRC-7	CRC-8	CRC-9	CRC-11
	Voltage Polarized	CRP-6	CRP-7	CRP-8	CRP-9	CRP-11
	Voltage and/or Current Polarized	CRD-6	CRD-7	CRD-8	CRD-9	CRD-11



Comparison of new CR directional overcurrent relay (left, lower) and older model (left, above); operating elements of new (right, lower) and old CR directional overcurrent relay (right, above). New elements are smaller and simplified, with improved accessibility.

TABLE III

Summary of CV voltage relay types.

Relay Type	Designation	Type of Protection
CV-1	Long Time	Undervoltage
CV-2	Short Time	Undervoltage
CV-4	Long Time	Overvoltage
CV-5	Short Time	Overvoltage
CV-6	Long Time	Over and Undervoltage
CV-7	Short Time	Over and Undervoltage
CV-8	Low Pick-Up	Overvoltage

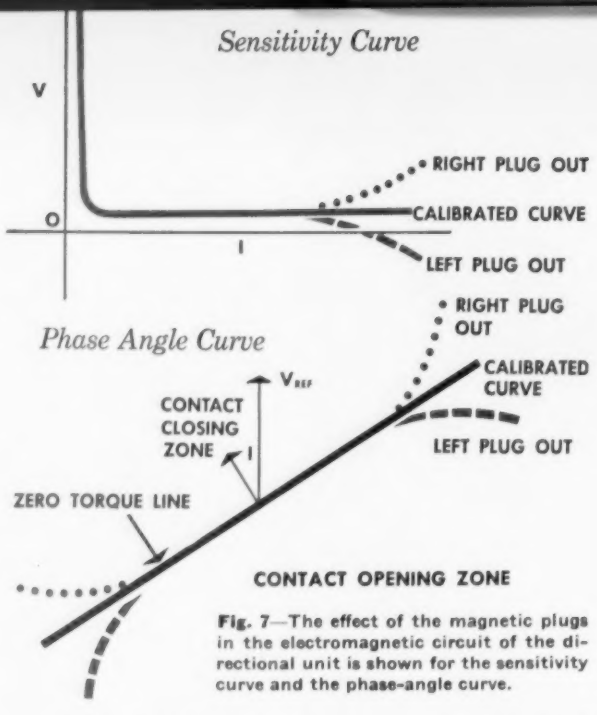


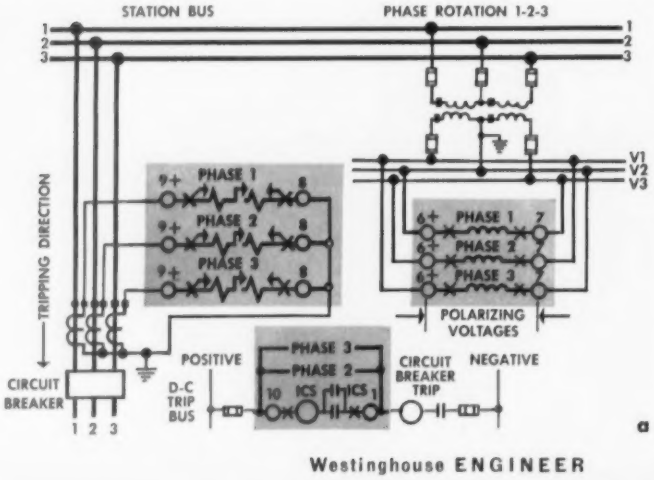
Fig. 7—The effect of the magnetic plugs in the electromagnetic circuit of the directional unit is shown for the sensitivity curve and the phase-angle curve.

required. In the prior design, the induction-disc directional unit used with the 90-degree connection had its maximum torque angle when load current lagged its 100-percent power factor position by 45 degrees.

The CRP voltage-polarized relay is used for ground-fault protection and operates from residual current and residual polarizing voltage (See Fig. 9a). Maximum torque angle of these CRP directional units occurs when the ground current lags the polarizing voltage by approximately 60 degrees. An internally-mounted phase shifter (resistor-capacitor) is used to obtain the desired maximum torque angle. Minimum pick-up of the CRP (current lagging voltage by 60 degrees) is the same as the CR relay.

The CRC current-polarized relay is also used for ground-fault protection and operates on residual ground current and residual polarizing current (Fig. 9b). Maximum torque angle occurs when the applied operating current leads the polarizing current by approximately 40 degrees. Minimum pickup of the CRC directional unit occurs when 0.5 ampere in-phase current flows in both the operating and polarizing circuits.

The type CRD is a dual-polarized relay and can be polarized from a current or voltage source independently or simultaneously. The CRD is also applied for ground-fault protec-



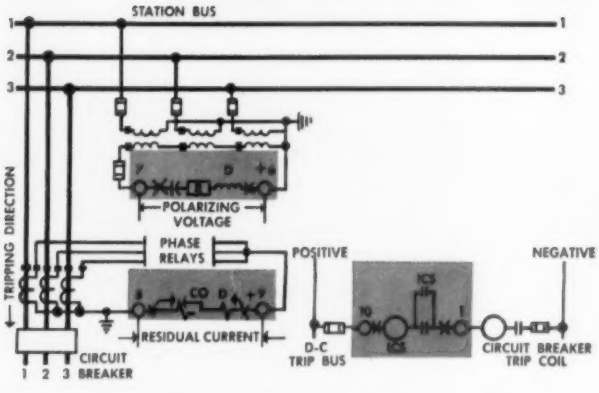


Fig. 9a—Application of CRP relays for ground protection.

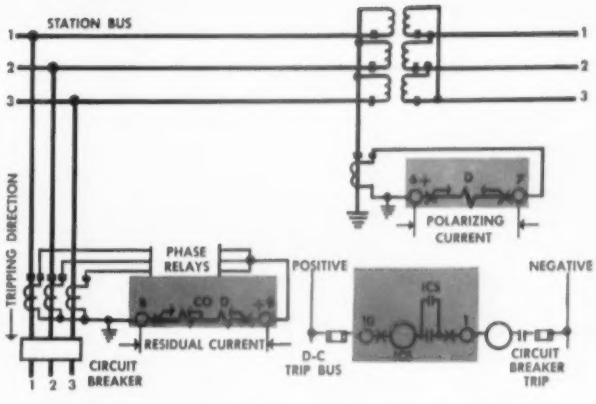


Fig. 9b—Application of CRC relays for ground protection.

tion and utilizes the directional units of the CRC and CRP relays. The contacts of both directional units are connected in parallel and control a common CO overcurrent unit. Use of two separate directional units eliminates magnetic coupling between the two polarizing circuits and affords greater reliability than a single unit.

VOLTAGE RELAYS

The CV voltage relay is similar in operation and design to the CO overcurrent relay, so that the "E" type electromagnet is also applied to the CV line of voltage relays. Since the voltage winding is a low-current, large-number-of-turns winding, magnetic plugs are not utilized in the electromagnet since saturation of the electromagnet does not take place over the operating range of the CV relay. The complete line of CV voltage relays is tabulated in Table III.

Former CV relay designs used a slide-wire resistor to vary initial pickup-voltage value. This resistor has been replaced by a tapped-operating coil on the electromagnet, resulting in higher continuous-voltage ratings for the relay. The new relay, with a nominal rating of 120 volts and taps from 55 to 140 volts, will withstand a continuous rating of 132 volts on all taps except for 140 volts continuous on the 140-volt tap. Prior designs withstood 110 percent of tap-value voltage.

Use of taps instead of a slide-wire resistor has also resulted in a greater range of time settings. For example, for the CV-2 short-time, under-voltage relay on the number 10 time-dial setting with 50 percent of tap-value voltage applied, the new CV-2 provides a time delay of 13.6 seconds as compared to 10.8 seconds in the prior design. Greater disc travel also provides greater spacing between the moving and stationary contacts at the lower time-dial settings.

The type CV-8 is a new addition to the CV line. This is a single relay with a self-contained internal third-harmonic filter, which nullifies the effect of third-harmonic current on the induction-disc voltage unit in the relay. The CV-8 is primarily used for protection of a-c windings of large generators that are grounded through a distribution transformer. The tuned-filter circuit of the CV-8 offers high impedance to third-harmonic voltage, and low impedance to 60-cycle voltages. The relay does not have taps but is rated 67 volts continuously and will pick up on 8 percent of this value, or 5.4 volts. The relay has adjustable time-dial settings to assure tripping on faults and not transient conditions. Time-delay ranges are from 1.5 cycles (60-cycle base) to approximately 4 seconds on the number 11 time-dial position.

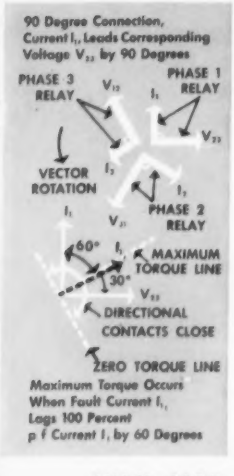

90 Degree Connection, Current I_1, Leads Corresponding Voltage V_{23} by 90 Degrees
PHASE 3 RELAY
PHASE 1 RELAY
PHASE 2 RELAY
VECTOR ROTATION
MAXIMUM TORQUE LINE
60°
30°
DIRECTIONAL CONTACTS CLOSE
ZERO TORQUE LINE
Maximum Torque Occurs When Fault Current I_1 Lags 100 Percent p f Current I_1 by 60 Degrees

Fig. 8—(a) Application of directional overcurrent relays for phase protection. Three single-phase type-CR relays are used. (b) Polarizing-voltage and operating-current vectors are shown for 100-percent power factor (top) and fault (bottom) conditions.

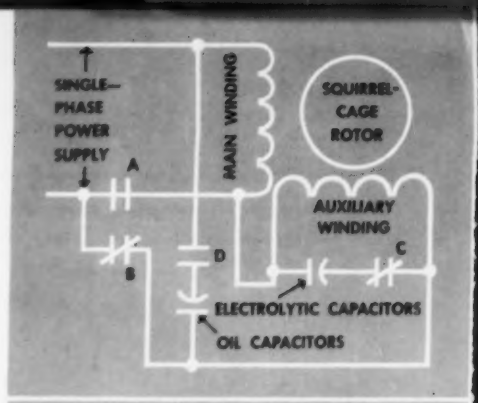
b

FLEXITEST CASE

Reduction in the sizes of the operating units in the CO, CR, and CV relays have permitted a new Flexitest case design. The primary design changes have involved provisions for making the same case suitable for both projection (surface) and semi-flush mounting, addition of approximately three-fourths inch to the case depth to provide room for auxiliaries such as resistors, plus a redesign of the current transformer short-circuiting switches and chassis frame. One-piece molded blocks provide a common mounting for the switch blades and strap-type connectors to the rear metallic connector terminals. This design eliminates the need for independently-mounted rear connector terminals and wiring, and greatly facilitates tracing electrical circuits from switch blade to terminal. The case shell is welded steel, which is zinc plated, bonderized, and coated with baked enamel to resist corrosion. Two newly designed current-transformer short-circuiting switches are provided in the new case. Contact position of the short-circuiting switches is readily visible from the front of the case even with the removable chassis unit within the case and the Flexitest switches closed or open.

The new designs of relay-operating units and cases permit panel mounting of eight new relays in the same panel space formerly required for five. New cases are the same width as the previous Flexitest cases but lower in height. For example, the new CR relay is now housed in the same case size used for the old CO unit. This size correspondence was intentional since power-system changes often require replacement of straight overcurrent (type CO) relays with directional overcurrent (type CR) relays.

The overall design program has resulted in a new line of relays with improved operating characteristics, lower burdens, improved mechanical construction with greater reliability and fewer parts, and simplified maintenance. ■



START: B AND C CONTACTS CLOSED; A AND D OPEN

RUN: A AND D CONTACTS CLOSED; B AND C OPEN

TRANSFER MECHANISM—NOT SHOWN

Fig. 2—The design of the 20-hp motor is similar to the smaller motors, with several exceptions.

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single-phase motors

GROW LARGER

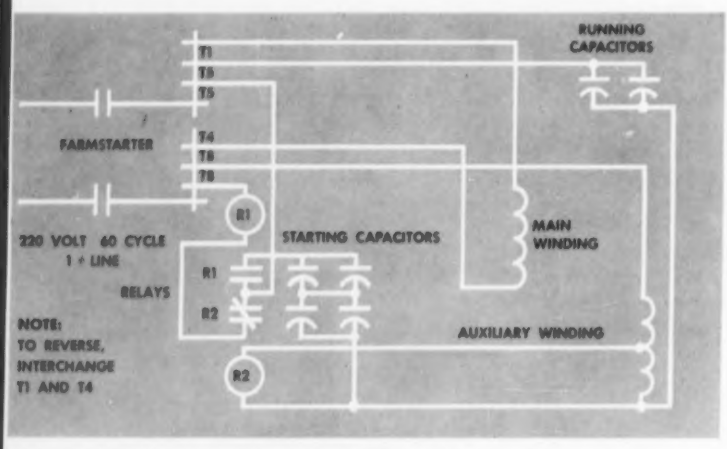

Fig. 1—A schematic diagram of 5, 7½, and 10-hp single-phase motors.

■ In many farm applications, and in some industrial plants, only single-phase power is available. This has been a limiting factor in the size of electric motors that could be used for such applications, and therefore has limited the number of uses.

The limitation on motor size is primarily due to the large starting current required by such motors. Single-phase motors of 5 and 7½ hp, 220 volts, 60 cycles are now common in single-phase application, and 10-hp motors are gradually coming into more wide use. In part, improved substations, better voltage regulation, and expanded generating capacity have made this possible. But improved motor design has also played a part—to the point where restrictions should no longer be made on the basis of horsepower rating alone. For example, a new 20-hp motor, recently developed, actually draws less starting current than the present 10-hp motor. The improved designs of large single-phase motors open up applications for electric power in many farms and industries.

DESIGN OF LARGE SINGLE-PHASE MOTORS

The most modern single-phase motors are of the capacitor type. Motors of 5 hp and above are of the capacitor-start and

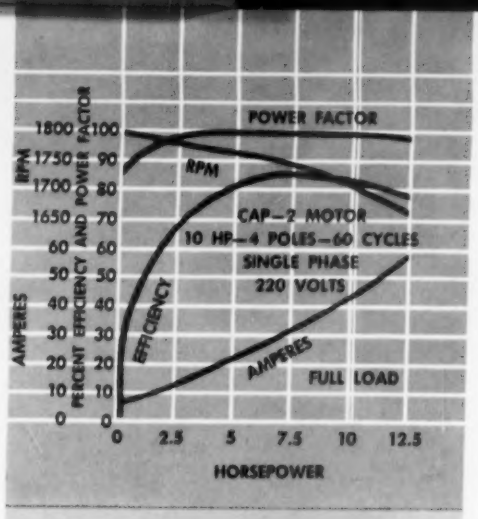

Fig. 3a—These are the performance curves for a 10-hp, 220-volt, four-pole, single-phase motor.

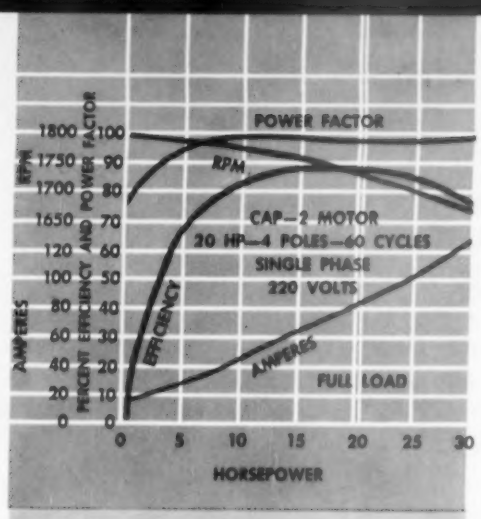

Fig. 3b—Performance curves for the special 20-hp motor, also 220-volt, four-pole, single-phase.

capacitor-run type. Consider first the design of the 5, 7½, and 10-hp motors. The schematic diagram of these motors is shown in Fig. 1. These motors have a main and an auxiliary winding, both of which are in the circuit at all times. Referring to the diagram, and the accompanying description, it is apparent that the starting capacitors and the running capacitors are in parallel during starting, and therefore their capacitance is added during this period. While different capacitors are used for different ratings, the design and operating sequence are the same for all three horsepower sizes.

The success of the 10-hp motor led to the development of a 20-hp motor, with the basic objective of holding the starting current of the larger motor to the same value, or less, than the 10-hp version. Such a motor has been developed, and, in fact, one such motor has been driving an irrigation pump on a Pennsylvania farm for about two years.

In general, the design of the 20-hp motor is similar to that of the smaller motors. However, during starting, the main and auxiliary windings are in series; when the motor is up to speed they are switched to parallel operation for running. A switching relay and two magnetic contactors are required, and these—together with capacitors and main line breaker—are located in a wall box separate from the motor. Overload protection and a pushbutton are incorporated. No additional control or disconnect switch is required with this special motor; other horsepower ratings require separate magnetic control and a means for disconnecting the equipment from the power line. A schematic diagram of this new motor is shown in Fig. 2.

PERFORMANCE OF LARGE MOTORS

Performance curves of the 10 and 20-hp motors are shown in Fig. 3. A tabulation of comparative values for the two motors is also shown below. Note that the starting current of the 20-hp motor is but 170 amperes compared to the starting current of 204 amperes for the 10-hp motor. Starting and accelerating characteristics of the two motors are comparable. One principal use for this new motor could be for irrigation pumping, where the large size of the motor and the convenience and reliability of electric motors are especially useful. Other general-purpose applications for this motor are in crop dryers, wood saws, and feed grinders. ■

	Starting Torque	Starting Current	Torque at Transfer	Current at Transfer	Breakdown Torque Running Conn.
Special 20-Hp Motor (220 Volts)	74 lb./ft.	170 Amps	100 lb./ft.	215 Amps	140 lb./ft.
Conventional 10-Hp Motor (220 Volts)	68 lb./ft.	204 Amps	95 lb./ft.	200 Amps	60 lb./ft.

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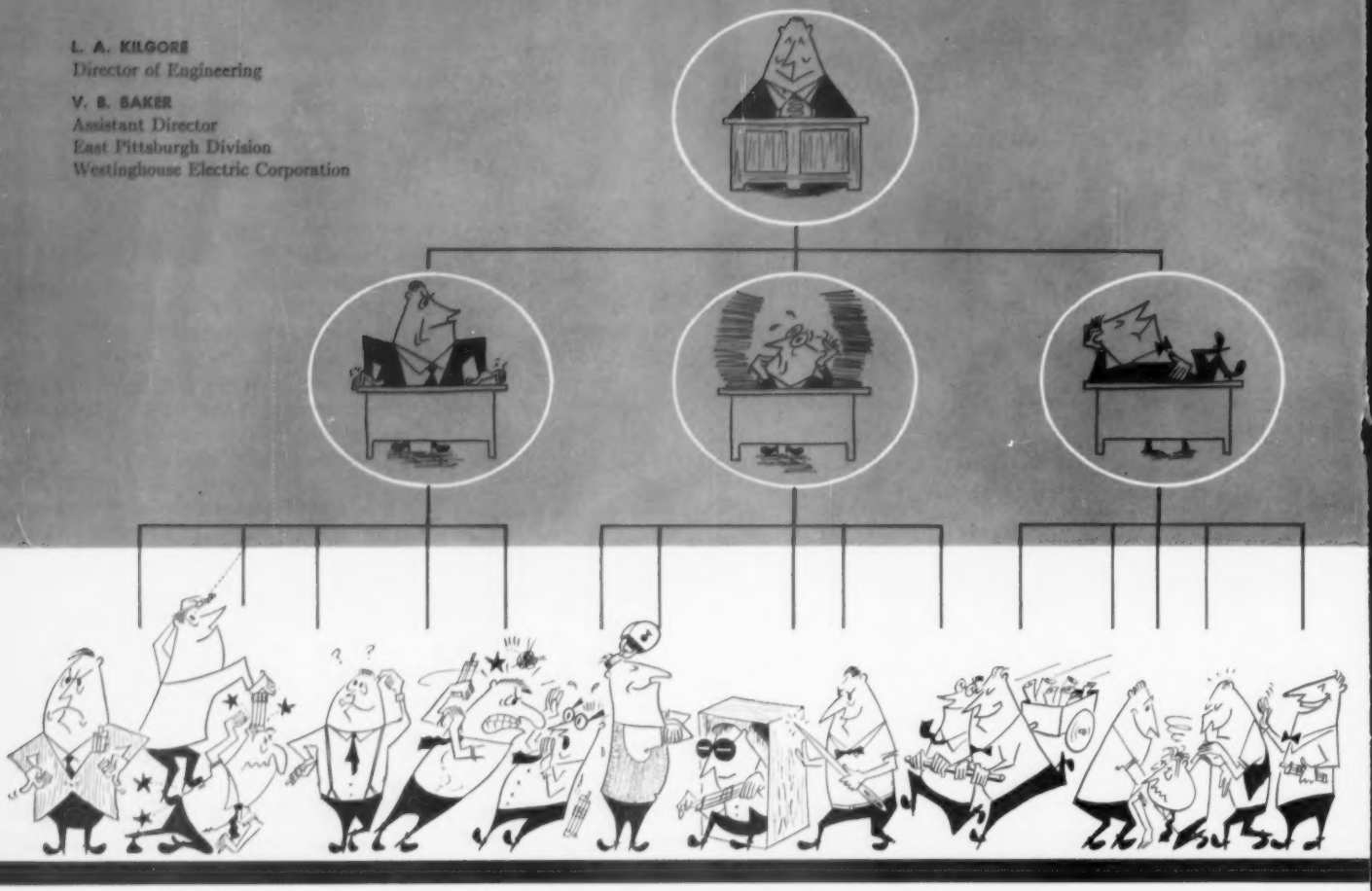


Human Relations and Engineers

Editor's Note: *Courses and seminars on human relations are nothing new in industry. Two years ago, however, several supervisors in the Westinghouse East Pittsburgh plant decided that the courses they were familiar with were not particularly suitable for engineers. So they set about organizing a course of their own, drawing freely upon available source material and personal experiences. Specifically, they felt that the course should be "down-to-earth", and that it should be designed to promote class discussion; also they felt that it should not delve deeply into the "whys" of human behavior, but rather should concentrate on specific suggestions for improvements in human relations that every engineer could adapt to his own needs.*

A prime objective for the course was to stir up individual thought on the problem, and promote an interest and an awareness of the possibilities for individual improvement. The points covered in this article were developed following discussion of basic human drives and reactions. These were discussed in terms of individual experiences of the members of the class.

The first course on human relations for engineers was organized by the authors of this article, and presented to engineering supervisors at East Pittsburgh. It was then extended to engineers, with some of the supervisors acting as leaders. Classes were held to not more than 30 men each, and were conducted with maximum participation. Enrollment was voluntary and the course was held over a period of eight evenings. To date, 104 of the 110 supervisors, and 375 of approximately 500 engineers to which the course has been offered have attended. The large turnout, plus the active class participation indicated a high interest in the subject.

The course offered no earth-shaking solutions to human-relations problems, nor was it intended to. As one engineer put it, "My first reaction to the course was that much of it was obvious. But as we progressed, it began to dawn on me that I was overlooking many of the things mentioned. It made me think about the subject in terms of my own daily experiences, and even if it had accomplished nothing more than that, it would have been worthwhile."

■ The engineer is often pictured as the man with the slide rule, a man of figures and facts. Actually this is only half of the picture, for everywhere he turns the engineer must deal with people—other engineers, the salesman, the shop man, his own boss. To do his job well, to win acceptance for himself and his ideas, the engineer must be able to deal effectively with all these people.

Today the engineer is more than ever a team worker. Engineers are teamed with scientists to work on development problems, and with sales and shop people in the planning and production of apparatus. They are called on to deal with customers on complex application and operating problems. Few engineers have had formal education in human relations and many have concentrated so much on their technical work that they have not benefited fully by their experience.

In this highly technical industrial and military world, the engineer is in a unique position to provide leadership. He is the man with the facts, the analytical methods, the creative mind. It is natural then that many engineers move into management jobs. All experienced engineers often need to exercise leadership. Some engineers are natural leaders. Each of us has probably known at least one man with whom everyone likes to work and whose ideas are always well received. Some analysis of his actions and characteristics may be helpful. Is it his enthusiasm, his genuine interest in others, his ability to make others feel important and part of the team, or what is it?

Then, too, we can get some help from reflecting on our own emotional reactions to the specific acts of others. What are the things that have made us feel good towards someone and want to go out of our way to cooperate?

This type of reflection leads to the conviction that there are some general rules of good practice in human relations.

RULES OF GOOD PRACTICE

Before we attempt to state any rules, let's consider a few problems. Some feel that rules cannot be made for dealing with people; they are impressed with the great differences in personalities, forgetting that there are many wants and reactions common to all. Other people feel that there is something basically dishonest about patterning their behavior after a standard set of rules. This would be true for those who could not learn to apply the rules naturally and with complete sincerity. For example, offering a forced or undeserved compliment to an associate frequently leaves both of you with a bad taste. Recognizing that the compliment is undeserved, he is suspicious of your motives; by the same token your conscience bothers you for being dishonest. On the other hand, a deserved compliment, sincerely delivered, improves attitudes on both sides; and how often we overlook a chance to give that sincere compliment. Developing a genuine interest in others makes it possible to do these things *naturally and sincerely*.

Develop a friendly, sincere attitude toward others.

This implies that, while general rules for better human relations can be laid down, each person must adapt them to his own personality and character in applying them.

With *sincerity* as the keynote the following rules are offered to be tested against your experience.

First, develop a *warm interest* in all the people with whom you deal. People respond to *genuine* interest in themselves, their work, their families, their hobbies. Moreover, you benefit substantially too—not only by acquiring broader interests, but also by the personal satisfaction gained. When this warm interest in people becomes habit, any individual subconsciously applies a great many effective techniques in dealing with others.

A *feeling of importance* is a strong human want in most of us. Therefore if we recognize that the other fellow is important, and *make him feel that way*—without resorting to insincere techniques—a receptive attitude may well result. Little things—like remembering his name, a sincere compliment, or an expression of confidence—help bring the other person close. Too often we overlook or forget these important "small" things in daily contacts.

Be enthusiastic. Enthusiasm is contagious and inspires others to greater effort. Too often enthusiasm is hidden behind a cloak of "sophistication," even though inwardly we feel highly enthusiastic. Along these lines, a point worth remembering is that with some people a critical attitude is an indication of interest that can be turned into enthusiasm.

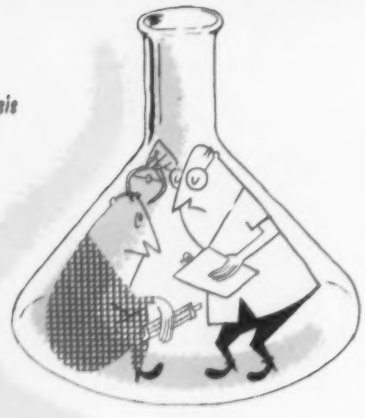
Maintain a positive attitude. Engineers must be analytical and critical of error, but they also have to get things done. Others respond much better when things are put in positive terms. By taking the positive approach, we help ourselves as well as others to find the best answer.

Give others a challenge. This often inspires and motivates people to their highest efforts. People usually respond with their best when they know someone has confidence in them.

An engineer is not just a man of facts and figures...

...he must also deal extensively with other people.

Cold scientific analysis is a poor substitute for warm human interest...



When faced with a difficult problem, a challenge may whet the imagination or kindle desire for achievement.

Many additional rules could be devised. A few might be: let the other fellow save face, consult with others, and show respect for their ideas. We should not attempt an all-inclusive set of rules, for human relations is an art, not an exact science. Also, a coldly scientific analysis of personality is a poor substitute for a warm human interest in the other fellow.

To some, the rules outlined here may represent too mild an approach, not suitable for all cases. One engineer has suggested three approaches to dealing with others:

1. The personal interest approach.
2. The objective, or impersonal, approach.
3. The hardboiled "do it or else" approach.

So far in this article only the first has been discussed. The objective approach can be used in many daily contacts where the other person is already interested and is ready and willing to do what is right. It may also be useful to us at those times when there is danger of losing control of our emotions. At such times, one ex-engineer says he tried to get this objectivity by thinking, "How will this situation look to me a week from now after things have cooled off?"

The "hardboiled" approach is one an engineer should need rarely, for he is usually dealing with reasonable people. But in rare cases you may encounter a person so ruthless that he will not respect you until he is shown that you will not be stepped on or ignored. Often we misunderstand another's motives unless we know him very well, hence the other fellow should be given the benefit of the doubt.

The "hardboiled" approach as a means of driving people through pressure or fear is poor motivation, especially when dealing with creative people. Resentment or fear of failure tend to inhibit creative thought and distort judgment.

Interest in the other fellow and consideration of his ideas do not weaken your position nor make you any less forceful. Actually an atmosphere of free interchange of ideas helps to gain cooperation and support. If by listening to the others you learn something, and occasionally admit to a mistake, people will respect you for an open mind.

COMMUNICATIONS

One important aspect of human relations is the much discussed subject of communications. What and how much to communicate up and down the line are worth considerable thought, but most important is the subject of *how to communicate*. Engineers have a problem common to any specialist, that of "talking the other fellow's language." The engineer must put himself in the other fellow's place to find the concepts and the words to put his technical ideas across. This applies whether he is talking to the shop man or the manager.

The art of listening is also an important part of good communications; it forms the "feedback." The response of the other fellow must be sensed in order to regulate and guide our own expression. Observing his voice and expression, as well as his words, places us in a much better position to control the situation than if we just plunge ahead blindly with our own thoughts and feelings. This sensitivity to others' feelings is one of the basic points of the human relations skill and is worth cultivating.

talk the other fellow's language...

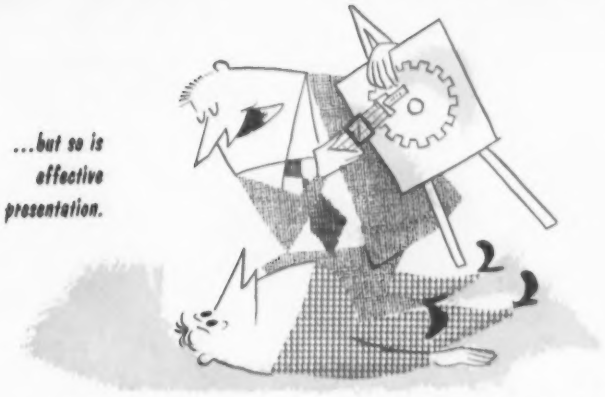
Part of good communications is effective presentation. Engineers are already good at logical thinking and organization, but not always adept at expression or salesmanship. Presenting a proposition or making a request is really an attempt to sell our ideas and ourselves.

Here is a sequence or a check list to help us organize our thoughts and actions:

1. *Get a receptive mood.* It's often worth a few minutes time to get the other fellow in the proper frame of mind.

Occasionally you find a person who won't respect you unless you get hardboiled...

The art of listening is an important part of communications...



...but so is effective presentation.

2. *Get attention.* Start in an area of mutual interest, related to the proposition.

3. *Build interest in the subject.* State the subject clearly and show him why he should be interested.

4. *Build desire.* Appeal to his wants, and to his principles, to his reason, and to his emotions. If you can, dramatize with a human interest story (to the point), and lead his imagination. But use judgment, don't oversell.

5. *Leave a clear understanding* of what is to be done. Get him to state what he will do, summarize it yourself, or give a command—whichever the situation demands.

LEADERSHIP

Leadership is one phase of human relations in which everyone is interested. There is a good deal more to leadership than just getting along with people, being persuasive, and having good communications—although these are certainly a part. *Integrity* is obviously a most important quality of leadership; but there are other qualities of an effective leader.

Respect of the group. People like to be led, but they want their leader to have at least one strong point—such as ability, or diplomacy, or courage. Whatever the quality, it must be something that other people recognize. No one should hesitate to stress his own strong points; however, this necessitates greater amounts of tact, diplomacy, and understanding. Make your good points show, but not to the point of being overbearing or inconsiderate.

Willingness to take responsibility. Again, others are usually glad to let you take the responsibility if you demonstrate the ability and the willingness, without being over-eager or reaching far beyond your ability.

Ability to create a team. People like to be a part of a good team. You as the leader have to demonstrate your interest in the group as a team and let them know what you expect of them as part of your team in accomplishing the objectives of the group.

Competition with another group tends to build team spirit but it can also work against cooperation. Competition with the accomplishments of another firm in the same field or with your own previous record is excellent.

Ability to correct faults tactfully, without discouraging others. No one likes criticism, but most people will accept correction, in private, if you display understanding and are just in your comments.

Devotion to the cause. It must be evident that you believe in your stated objectives; then your example will be a major factor in motivating others. Enthusiasm is contagious and perseverance provides stability in time of difficulty.

Intellectual courage. In engineering leadership, you must face all of the stubborn facts, weigh the risk of the unknowns, and make a decision. People respect and will follow an engineer who has a purpose and a plan, and the courage to act on his convictions.

CONCLUSION

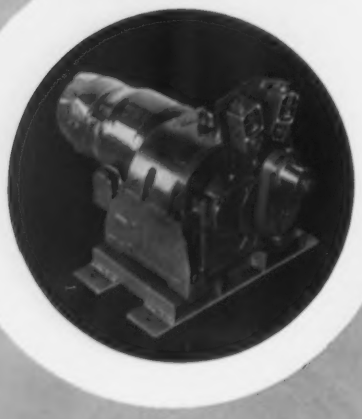
To make the most of their technical abilities, engineers need to be effective in dealing with people. The keys to actual improvement are sincerity and practice. This involves remembering to do something about it at every opportunity. "Get interested in the other fellow" is an important objective. A warm human interest assures that our attitude toward him will be right. This interest will help to open the door to better communication and it will bring to mind the other techniques that can contribute to effective dealings with him.

Serious effort to improve our human relations is worthwhile. To be more effective on the job . . . to have our ideas more readily accepted and our counsel more eagerly sought . . . these objectives warrant the best efforts of any man. ■

Leadership requires the ability to build teamwork...

Motocylinders

a new tool for Machine Designers



Typical motocylinder with flange-mounted brake, crank arm, limit switches, and adjusting cams.

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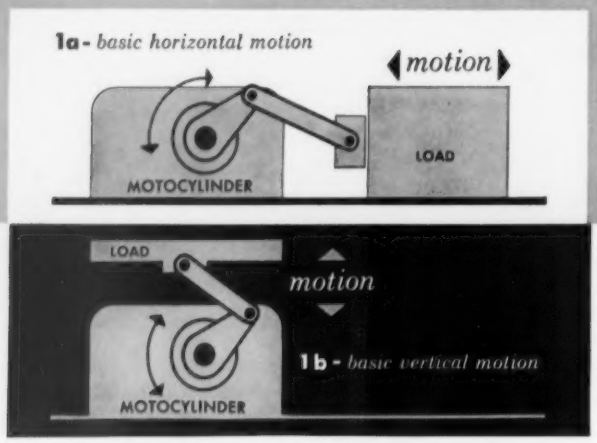


Fig. 1.—Basic operation of a motocylinder.

■ A motocylinder can be used on most machines where reciprocating motion is required. Suitably applied, it can perform functions that are now being done with pneumatic and hydraulic cylinders. For example, in the automotive industry, motocylinders can be used on shuttle-transfer mechanisms, welding presses, and numerous transfer and indexing devices.

A motocylinder is an electric-motor driven, geared thrustor. This simple electromechanical device consists of an electric motor driving the high-speed shaft of a gear unit; a crank arm on the slow-speed output shaft of the gear unit imparts reciprocating motion to the driven machine. Limit switches operated by the crank arm provide the necessary intelligence for stopping and starting the motocylinder at a desired position. If mechanical braking is desired, a disc-type brake is flange mounted to the motor. A motocylinder with a flange-mounted mechanical brake is shown above.

Unlike a flywheel and clutch-press operation, the motor is started and stopped every cycle, obviating any clutches between the motor and load. Some advantages of a motocylinder are: (1) Only electric power is required for complete operation of the drive—a factor that has become of major economic importance in the selection of this type of drive. In most cases the initial investment will be lowest when motocylinders are adopted. (2) No air or oil supplies, with possible leakage and complicated piping, are required. Likewise, standby losses and pressure build-up is not a problem. (3) Cycle times up to 1200 operations per hour are realistic. This duty cycle is possible because the motocylinder is not dependent upon system pressure build-up. (4) Inherent advantages of simple harmonic motion are available with the resulting sine wave velocity curve of the load. (5) This type of system has low maintenance because of the simple electromechanical scheme and uncomplicated control required. Solenoids are not required for operation of this drive. (6) The motor returns electrical power to the power system during a portion of the cycle period. (7) Both electric and mechanical braking can be used, with electric braking having the advantage of lower maintenance and easy adjustment. (8) Because of the simple control, the motocylinder can easily be interlocked with existing control schemes.

The motocylinder was originally developed for the lumber industry in the Pacific Northwest to replace costly steam and air cylinders. While steam cylinders exert a large thrust for their size and cost, they are very wasteful of steam. This waste was unimportant in the past when a large quantity of waste was available for fuel. However, in recent years this waste has been reclaimed for more productive uses; thus the principal advantage of steam cylinders disappeared.

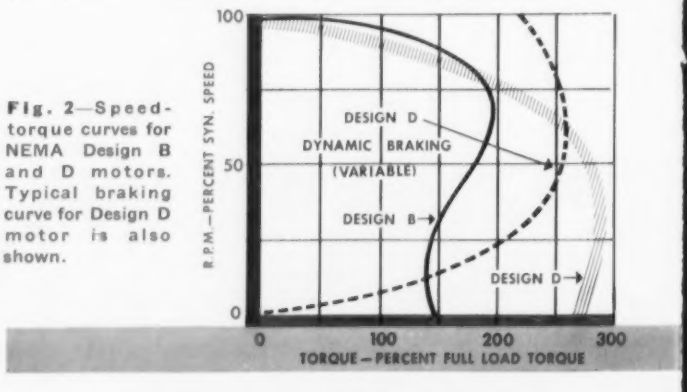


Fig. 2—Speed-torque curves for NEMA Design B and D motors. Typical braking curve for Design D motor is also shown.

MOTOCYLINDER OPERATING CHARACTERISTICS

The motocylinder has two basic motions; loads can be moved in a vertical plane and in a horizontal plane. Any configuration other than these basic motions is a combination of the two motions. In any case, load velocity follows a modified sine function; load acceleration follows a modified cosine function shown in Fig. 3. Load accelerating periods are always from 0 degrees to 90 degrees, and 180 degrees to 270 degrees; load decelerating periods 90 degrees to 180 degrees, and 270 degrees to 360 degrees crank rotation.

A feature of this drive is that during deceleration the load may be overhauling the motor, so that power is returned to the system, resulting in a net power saving.

For horizontal movement, power is returned to the power system during the decelerating periods only if the friction load is small, because of the counter torque required from the motocylinder.

For vertical motion, the initial decelerating counter torque (90 to 180 degrees) is aided by the gravitational force of the load so that little if any power is returned to the system when the load is raised. However, when the load is lowered (180 to 360 degrees) the drive must exert counter torque continually and power is returned to the power system during the complete lowering period. Consequently, load motion is slowed down by this generating action and load braking, whether mechanical or dynamic, need not be applied until the last few degrees of crank rotation. Thus, when most of the braking is done by the motor, size of the braking system can be kept to a minimum.

The motocylinder drive is a 1200-rpm NEMA Design-D hoist-type induction motor, totally enclosed and non-ventilated, with a minimum pull-out torque of 275 percent. For comparison, speed-torque curves of the conventional NEMA Design-B and NEMA Design-D motors are shown in Fig. 2.

The high-torque capabilities of the NEMA Design-D motor provide rapid acceleration of the motor rotor. Because of the crank motion, the inertia of the motor rotor and the inertia of the load are not accelerated at the same time. Little load inertia is reflected to the motor during initial motor acceleration, and the motor is up to speed in a few degrees rotation of the crank arm. Hence, motor accelerating and decelerating losses are kept to a minimum. With the high torque available, the drive can be jogged through the 90-degree portion of the load cycle where maximum motor loading exists.

Another feature of the NEMA Design-D motor is its inherent capability of starting and stopping more times a minute than the NEMA Design-B motor. This gives the Design-D motor a decided advantage in applications where the maximum number of cycles per minute is critical.

Two types of braking can be used with the motocylinder; the conventional disc-type friction brake, which is flange mounted to the motor, or dynamic braking.

Mechanical braking should be used where an overhanging load when the drive is stopped would cause the system to creep. Of course, the disadvantage of this method is the maintenance required by the brake and the addition of brake-drum inertia to the system, generally reducing the available cycles per hour. When mechanical braking is applied, only a conventional motor starter interlocked with the motocylinder limit switches is required.

Dynamic braking consists of removing the a-c voltage from the motor and applying direct current to two motor windings. This causes the motor to act as a generator, which is loaded by the induced current flowing through its squirrel-cage rotor winding. The amount of braking is determined by the magnitude of direct current applied. A speed-torque braking curve for an NEMA Design-D motor is shown in Fig. 2. With dynamic braking, no mechanical parts are added to motor-cylinder and more cycles per hour can be realized, but braking torque is absent at zero speed.

MOTOCYLINDER APPLICATION

An excellent example of a vertical-motion motocylinder application now in service is a press welder for welding a multiplicity of automotive parts (Fig. 5). Operation of the press welder is similar to a conventional press except the press is stopped in the *Up* position. The part to be welded is placed in the fixture on the platen while the machine is in the *Down* position. The operator initiates the cycle by pushbuttons, the motocylinder crank arm rotates 180 degrees, and the drive is dynamically braked to a stop. The welding guns are brought out automatically and the part welded. Once the weld is made, the weld timer signals the motocylinder control and the platen is returned to the *Down* position where the welded part is removed. This press welder is capable of operating 1200 cycles an hour.

Dynamic braking is used to good advantage in this application. The press welder is designed so that when it is in the *Weld* position the mechanical linkage has an overcenter feature; this prevents the downward force of the welding guns from rotating the drive without the use of a holding brake. Also, this type of linkage does not have accurate stopping requirements.

Fig. 3—Load velocity and acceleration curves for a motocylinder which is stopped at the 180-degree position.

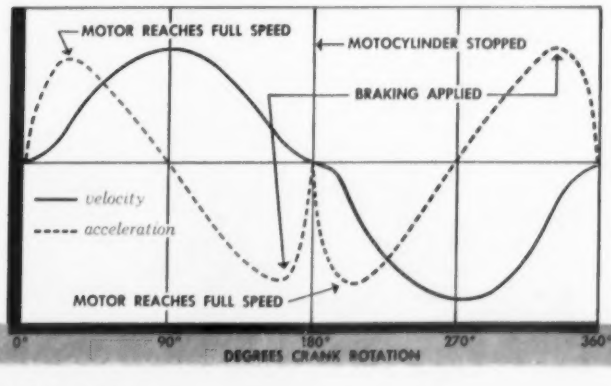
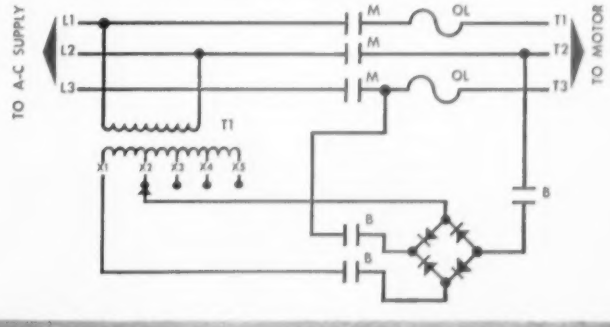


Fig. 4—Dynamic braking control, which applies direct current to the windings of an induction motor for stopping.



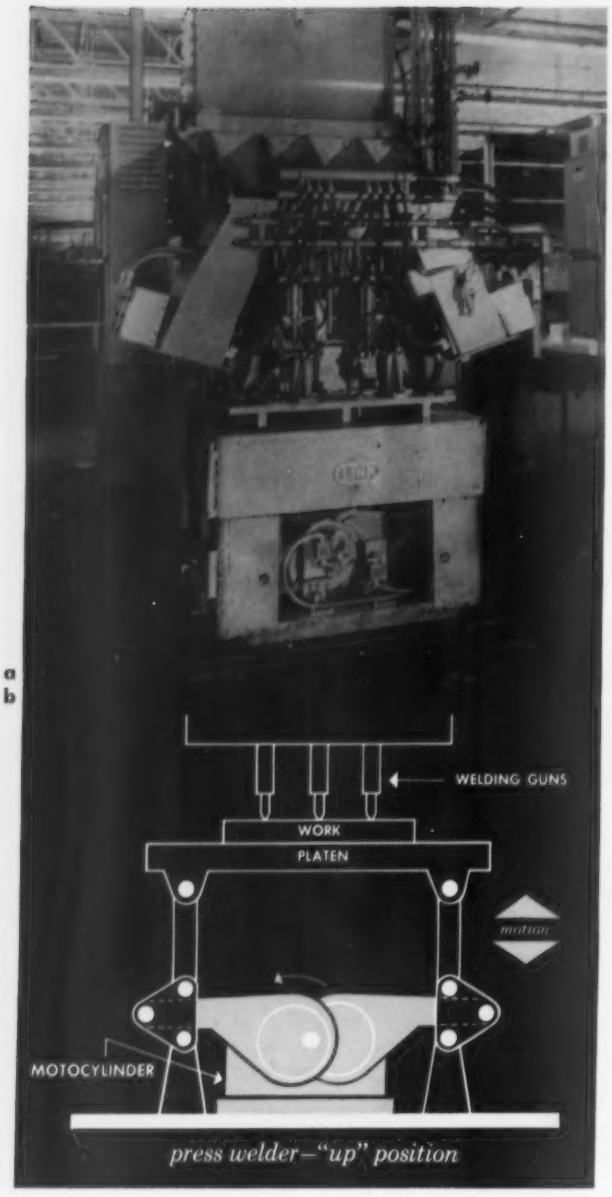


Fig. 5a—A motocylinder-operated press welder. Motocylinder is five horsepower and uses dynamic braking. (**b**) Simplified press welder diagram. Vertical reciprocating motion is imparted by motocylinder-mounted cams and a mechanical knee system.

An example of a motocylinder operating in a horizontal plane is a transfer machine, which transfers clutch covers between press operation (Fig. 6). The motocylinder drives the transfer mechanism through a rack-and-pinion system, which produces horizontal movement of the machine. On the forward stroke the clutch cover is transferred into the entry side of a press. After the stamping or drawing operation and the return stroke is completed, the clutch cover is removed from the opposite side of the press and transferred to the next press on the following forward stroke. A conventional disc-type brake was used on this motocylinder because the system requires holding torque at zero speed.

The size motocylinder required for a typical application can be illustrated for a shuttle-type transfer machine used for transferring engine blocks in a broaching operation (Fig. 7). The total weight to be indexed is 10 000 pounds, which produces a horizontal friction force of approximately 2000 pounds. The cycle is as follows: the loaded forward stroke transfers the load in one and one-half seconds; the drive remains at rest for two seconds while the dogs are retracted; the unloaded return stroke is made in one and one-half seconds; and the final dwell time is four seconds while the machining operation is performed. The complete cycle time is nine seconds, which provides 400 operations per hour. The rating of the motocylinder to accomplish this is seven and one-half horsepower.

Only a brief outline of the method of approach for obtaining this motocylinder drive rating will be given here. The drive rating for any motocylinder must be chosen to satisfy two basic requirements. First, the torque required by the load should not exceed 250 percent of the full-load rating of the motor; and second, the motor frame must be capable of dissipating the heat losses for a given duty cycle without exceeding its rated-temperature rise. In this case, a maximum torque of 44 foot-pounds is encountered, which requires a rating of five horsepower, or better. It can be shown that a 7½ hp motor with class B insulation (75-degree C rise) would have sufficient heat-dissipating capacity for the engine-block transfer machine described. Dynamic braking would be applied in this application because of the absence of load at zero speed.

The motocylinder makes possible new and effective methods for powering high-duty cycle machines in the automotive industry. In most applications requiring reciprocating or oscillating forms of motion the motocylinder is a versatile drive that can be easily applied. It is simple in operation, has low maintenance, requires only one source of power and provides the advantages of simple harmonic motion. Cycle times up to 1200 operations per hour are realistic with a minimum consumption of power and low investment cost. ■

Fig. 6—Diagrammatic sketch of a motocylinder-driven transfer table. Motocylinder operates through a rack-and-pinion system.

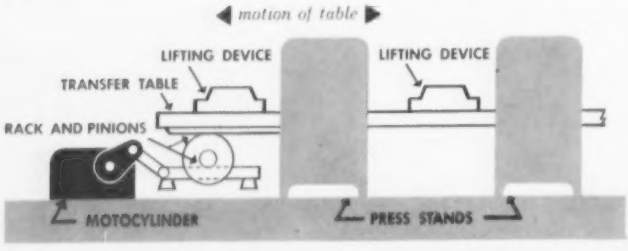
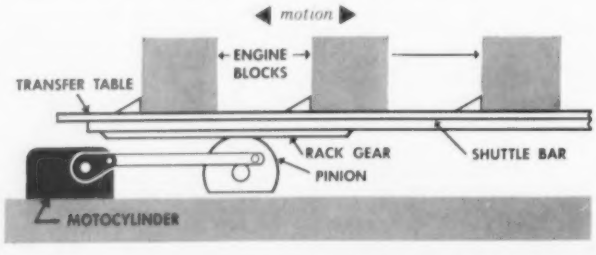


Fig. 7—Diagrammatic sketch of a typical shuttle-type transfer machine for pushing blocks in a broaching operation.



Personality Profiles

C. W. Upton • R. L. Wright • B. P. Hess • C. B. Hathaway and F. E. Spindler • G. Marieni and W. Stepanuk • L. A. Kilgore and V. B. Baker • P. A. Rabideau

• *C. W. Upton* came to Westinghouse with a BSME from the University of Pittsburgh in 1947. World War II interposed 3½ years of Air Force service into his college education, two of which were spent in "hibernation" (we quote Mr. Upton directly) in the Aleutians. He was discharged a Captain.

After six months on the Graduate Student Course, Upton joined the disconnect switch section of the Switchgear Division, and worked on outdoor switching equipment. In 1954, he was made Supervising Engineer on switches; two years later, he became Section Manager of the disconnect switch and outdoor substation section. Upton is an appropriate author for the SF_6 load-break switch and grounding switch article in this issue—he helped develop the former, and is co-inventor of the latter.

• *R. L. Wright* joined Westinghouse in 1943. During most of the time he has worked on circuits of various kinds. Among others, he worked out the circuits for the Westinghouse chest survey x-ray unit, and the Fluoradex "500." Some three years ago he was assigned to improve supervisory instruments for steam turbines; his article indicates part of his efforts.

Away from work Wright is busily engaged in trying to keep up with his three vigorous sons, who range from Bobcat Cub to Eagle Scout. The boys have him working as a PTA Vice President and as a scout leader.

• When *B. P. Hess* writes of any phase of farm electrification he is on particularly solid ground. Raised on a farm in southwestern Ohio, he earned his BS in Agriculture from Ohio State University in 1922. After a few years of work he returned to school and got his BEE in 1930, and joined Westinghouse.

Quite naturally, Hess helped form a Rural Electrification Department after leaving the Graduate Student Course. He has had a part in that activity ever since.

At present, as a member of the Industrial Sales Department, Hess handles farm resale, and the food, glass, and ceramic industries. He is an avid gardener, and a past president of the Men's Garden Club of Pittsburgh; also, he has been active in the American Society of Agricultural Engineers since 1922.

• Both of the authors of the d-c motor article —*C. B. Hathaway* and *F. E. Spindler*—have played a part in the development of the new machine. As far as Hathaway is concerned, this is the latest of many d-c designs he has been concerned with. A graduate of Ohio State University, he came directly to Westinghouse. He was selected to attend Engineering Design School, and after completing it, went to work in the d-c design department. His entire service with the company has been in d-c design, so he is eminently qualified to write on the subject. While Hathaway's principal hobby is photography, he has recently acquired a new one. Having obtained several kits for assembling testing units, he now is waiting patiently for the television set to break down so he can try his hand at repairing it.

Spindler, a University of Colorado graduate with a BS in EE in 1948, also came directly to the Graduate Student Course. Like Hathaway, he was selected for Design School, which he completed before getting his first permanent assignment. After this, he joined the transportation section of Industry Engineering, where he dealt with diesel-electric locomotive applications and special studies ranging from future military vehicles to railroad maintenance practices. In 1952, he earned his master's degree at the University of Pittsburgh, under the Westinghouse Evening Study Program. In 1955, Spindler was selected to attend Harvard Business School, where he earned his MBA in 1956. Since June 1956 he has been assistant to the manager of the Motor Department, where one of his prime tasks has been work on the new d-c motor.

• Capsule-version biographies of *Gino Marieni* and *Walter Stepanuk* read quite similarly, which is perhaps fitting for coauthors. Both were in the military service from 1943 to 1946, both graduated from college and came on the Graduate Student Course in 1951, settled permanently in the Newark Meter Division in 1952, and both are now Senior Design Engineers.

However, closer inspection does reveal some differences, which Gino and Walter probably consider quite significant: Marieni was a marine, and has an electrical engineering degree from the University of Missouri (although his home state is Connecticut); Stepanuk was a sailor, and has a mechanical engineering degree from Newark College of Engineering (his first two years were spent at Oklahoma University).

Back to similarities, both contributed materially to the development of the new line of relays described in this issue.

• In his four previous appearances in the ENGINEER, *L. A. Kilgore* has written about large complex machinery—giant motors and generators in particular. This time he and coauthor *V. B. Baker* tackle the even more complex subject of human relations. While neither of them profess to be experts in this field, they were largely responsible for successful courses on this subject conducted in their division.

Kilgore, a native of Nebraska, came to Westinghouse from the University of Nebraska in 1927, shortly after earning his BS in Electrical Engineering. Since then he has added an MS from the University of Pittsburgh, and an EE and an honorary doctor's degree from his alma mater. Big equipment has been a part of his career since he finished the Graduate Student Course in 1928. Mostly he has been concerned with the engineering of large motors, generators, rectifiers and electric couplings built at East Pittsburgh. Since Kilgore came to the division, he has had a progression of jobs, ranging from straight engineering to engineering supervision. He is now Director of Engineering for the East Pittsburgh Division.

Baker is a University of Colorado graduate, class of 1938. After a year of graduate work at the University of Missouri, he joined Westinghouse on the Graduate Student Course. His first permanent assignment was in the Industry Engineering Department, where he concentrated on the application of equipment to the pulp and paper industries. For two years during the war, he was assigned to the control engineering department to develop special electronic drives and controls required by the Armed Forces. In 1948, Baker became manager of the general mill section of Industry Engineering, the section that applies electrical equipment to a variety of industries, including pulp and paper, rubber, textile, and lumber. In 1952, he was appointed to the staff of the Vice President in Charge of Engineering. In 1955, Baker transferred to East Pittsburgh where he became Assistant Director of Engineering. Here he has primary responsibility for developing and coordinating engineering applications of computers in the East Pittsburgh Division.

• *P. A. Rabideau* came to Westinghouse with a BSEE from the University of Washington in 1951. He completed the Service Training Program in the spring of 1952, and worked as a service engineer out of the Cincinnati district office until the spring of 1955, when he was transferred to his present position as a Consulting and Application Engineer in the Detroit office. His principal engineering duties with the steel and automotive industries give him a ready opportunity for applying the moto-cylinder, of which he writes in this issue.

Having been raised in the State of Washington, Rabideau's fondness for camping, hunting, and fishing comes naturally. During the summer vacations of his junior and senior college years, he put this love of the great outdoors to a practical use; he was a "smoke jumper" for the U.S. Forest Service. (Upon sighting a wisp of smoke in the forest, a team of jumpers is flown to the scene and dropped in by parachute.) Sounds rough, but fun—if you like the great outdoors as much as Rabideau.

Soap bubbles illustrate how atoms group themselves into orderly arrangements, or "crystal structures." Because soap bubbles have a tendency to join and balance in much the same way as atoms do, this "bubble" technique duplicates actual atomic crystal structures, of which all metals are composed. Research scientists can thus "see" and investigate on a vastly larger scale the patterns and defect structures formed by atoms in nature. In an actual crystal structure, the space between each atom would be six million times smaller than those shown between the soap bubble "atoms."